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INHERITANCE OF SYNDACTYLISM, BLACK, AND DILUTION IN SWINE[1]

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Our present point of view in animal and plant breeding is being shaped to a large extent by experiments in the field of genetics. Probably the plant breeders have profited more by these experiments than the animal breeders; for there are relatively few precise observations on inheritance in domestic mammals, for obvious reasons. While the animal breeder can not afford to neglect the conclusions obtained with pedigreed cultures of laboratory material, nevertheless the data accumulated directly from domestic mammals will more quickly stimulate clear thinking and intelligent practice. For these reasons, among others, the following observations are presented and put on record.

The data in this study are derived from an original cross between a single pure-bred registered mule-foot boar and a number of pure-bred Duroc-Jersey sows, eligible to registration. Both boar and sows were owned by Mr. J. H. Percival, of Champaign, Ill. The results of the cross were so striking and uniform that we were invited to examine the progeny born in the fall litters of 1915 and in the spring litters of 1916. All the F_1 offspring, about 250 in number,[3] were self-colored black and mule-footed. Furthermore, the progeny resembled the mule-foot boar in general conformation (in which, as a matter of fact, both the sire and the Duroc-Jersey sows were much alike). The case is a good illustration of one type of prepotency, where the sire is homozygous in a number of conspicuous dominant characters, such as black and mule-foot in this particular instance. But the progeny inherited as much from their dams as they did from the sire, as the next generation showed. The vigorous hybrids were raised for the market and not for further breeding purposes, as is the case generally with such hybrids. Since the material seemed

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[3] The number of F_1 young in this paper is conservatively estimated at about 250. The exact number can not be given because the animals were kept in a large pasture, which made an exact count difficult. There is no doubt, however, that all F_1 individuals were black and mule-footed.

promising for further genetic investigation, six F_1 sows were purchased in June, 1916.

The six sows, numbered 1 to 6 in Tables I and II, were bred back to a Duroc-Jersey boar, since this type was recessive in a number of characters in the original cross. Each female, except ♀ 5, gave at least one litter, and ♀ 3 gave two litters. A total of 42 F_2 offspring by this backcross was thus obtained. The original mule-foot P_1 parent was without doubt homozygous in mule-foot and black and probably had the genetic formula BBMM, where B is a factor for black and M is a factor for mule-foot. The Duroc-Jerseys had the genetic formula bbmm, where b stands for red, and m for cloven-foot. The F_1 hybrids were then heterozygous in both black and mule-foot (BbMm) and, if the case is one of simple Mendelism, produced gametes BM+Bm+bM+bm with equal frequency. Mating the F_1 females to the Duroc-Jersey male should give in Mendelian terms:

BM+	Bm+	bM+	bm	F_1 gametes
bm+	bm			Duroc-Jersey gametes
BbMm +	Bbmm +	bbMm +	bbmm	F_2 zygotes
black	black	red	red	
mule-foot	cloven	mule-foot	cloven	

That is, the F_2 classes would be of four equally frequent types. The calculated and observed results agree, for there were produced 8 black mule-foot, 11 black cloven-foot, 9 red mule-foot, and 14 red cloven-foot where 10.5 of each kind is the calculated result. (See Pl. 70.) So far as the evidence goes, the allelomorphic pair of factors for syndactylism and cloven-foot is quite independent of the allelomorphic pair for black and red. The ultimate recessive segregates, red cloven, bred true when mated *inter se* and gave 30 red cloven in the F_3 and F_4 generations.

TABLE I.—*Distribution of F_2 segregates from mule-foot×Duroc-Jersey F_1 hybrids mated back to Duroc-Jersey*

Dam No.	Offspring.								Total.
	Males.				Females.				
	Black mule-foot.	Black cloven-foot.	Red mule-foot.	Red cloven-foot.	Black mule-foot.	Black cloven-foot.	Red mule-foot.	Red cloven-foot.	
1			1				3	2	6
2		4	1					3	8
3	1	2				2			5
3	1			3		1	1	1	7
4		1	1	1	2	1	1	1	8
6	2			3	2		1		8
Total	4	7	3	7	4	4	6	7	42

TABLE II.—*Original data on the F_2, F_3, and F_4 offspring from a cross of a mule-foot boar on Duroc-Jersey sows*

F_1 Dam No.	Duroc-Jersey sire.	Offspring No.	Sex.	Color.	Foot character.	Date of birth.	Remarks.
1	Good Colonel, No. 41517	1 a	♀	Red	Cloven	Nov. 8, 1916	
		1 b	♀	Yellow	do		
		1 c	♂	Cream	Mule		
		1 d	♀	do	do		
		1 e	♀	Lemon	do		
		1 f	♀	Yellow	do		
2	do	2 a	♂	Black	Cloven	Mar. 7, 1917	
		2 b	♂	do	do		
		2 c	♂	do	do		
		2 d	♂	do	do		
		2 e	♀	Yellow	do		Saved for breeding.
		2 f	♀	Lemon	do		Do.
		2 g	♀	Red	do		
		2 h	♂	Yellow	Mule		
3	do	3 a	♀	Black	Cloven	Nov. 8, 1916	
		3 b	♀	do	do		
		3 c	♂	do	do		
		3 d	♂	do	do		
		3 e	♂	do	Mule		
3	do	3 f	♂	Yellow	Cloven	Mar. 13, 1917	Saved for breeding.
		3 g	♂	Black	Mule		
		3 h	♂	Yellow	Cloven		
		3 i	♂	do	do		
		3 j	♀	Black	do		Some roan.
		3 k	♀	Cream	Mule		
		3 l	♀	Red	Cloven		
4	do	4 a	♀	Black	do	Jan. 19, 1917	
		4 b	♀	do	Mule		
		4 c	♀	do	do		
		4 d	♀	Yellow	do		
		4 e	♀	Cream	Cloven		Some roan.
		4 f	♂	do	Mule		
		4 g	♂	Red	Cloven		
		4 h	♂	Black	do		
6	do	6 a	♂	Yellow	do	Apr. 8, 1917	Slightly roan.
		6 b	♂	Cream	do		
		6 c	♂	Red	do		Much roan.
		6 d	♂	Black	Mule		
		6 e	♂	do	do		
		6 f	♀	Red	do		
		6 g	♀	Black	do		
		6 h	♀	do	do		White spot on upper lip.

F_2 dam No.	F_3 sire No.	Offspring No.	Sex.	Color.	Foot character.	Date of birth.	Remarks.
2 e	3 f	2e–a	♂	Red	Cloven	Mar. 1, 1918	Some doubt as to degree of red in this litter.
		2e–b	♂	do	do		
		2e–c	♂	do	do		
		2e–d	♂	do	do		
		2e–e	♀	do	do		

TABLE II.—*Original data on the F_2, F_3, and F_4 offspring from a cross of a mule-foot boar on Duroc-Jersey sows*—Continued.

F_2 dam No.	F_2 sire No.	Offspring No.	Sex.	Color.	Foot character.	Date of birth.	Remarks.
2 f.....	3 f.....	2f–a	♂	Cream.	..do....	Mar. 5, 1918	Saved for breeding.
		2f–b	♀	..do....	..do....		Do.
		2f–c	♀	..do....	..do....		Do.
		2f–d	♀	..do....	..do....		
		2f–e	♀	..do....	..do....		
		2f–f	♂	Yellow.	..do....		
		2f–g	♂	..do....	..do....		
		2f–h	♂	..do....	..do....		
		2f–i	♂	..do....	..do....		
		2f–j	♀	..do....	..do....		
		2f–k	♀	..do....	..do....		
		2f–l	♀	..do....	..do....		
		2f–m	♀	..do....	..do....		

F_3 dam No.	F_3 sire No.	Offspring No.	Sex.	Color.	Foot character.	Date of birth.	Remarks.
2f-b....	2f-a.....	2f–b–a	♂	Cream.	Cloven	Mar. 18, 1919	Lemon on top of head and shoulders.
		2f–b–b	♀	..do....	..do....		
		2f–b–c	♀	..do....	..do....		
		2f–b–d	♀	..do....	..do....		
2f-c....	2f-a.....	2f–c–a	♂	Cream.	..do....	Apr. 16, 1919	Few yellow hairs between ears.
		2f–c–b	♀	..do....	..do....		
		2f–c–c	♀	..do....	..do....		
		2f–c–d	♂	Yellow.	..do....		
		2f–c–e	♂	Red....	..do....		
		2f–c–f	♂	Yellow.	..do....		
		2f–c–g	♀	..do....	..do....		
		2f–c–h	♀	Cream.	..do....		

Syndactylism has been recognized as an inherited character in man by Lewis and Embleton (*6*),[1] Lewis (*5*), and Pearson (*7*); in poultry by Davenport (*3*); and in swine by Spillman (*9*). In man there is probably one main dominant factor allelomorphic to normal; and the case shows simple Mendelism as we now understand it, although both Lewis and Embleton and Pearson were not inclined to such a view. In poultry, Davenport concluded that syndactylism was very imperfectly dominant to its allelomorph, normal toes. Syndactylism versus cloven-foot in swine has been cited as an illustration of monohybridism in a number of textbooks, but no published data are available. Spillman states:

> It is interesting to note that in crosses between mule-foot hogs and ordinary breeds the mule-foot character seems to be dominant.

[1] Reference is made by number (italic) to "Literature cited," p. 604.

No statement is made regarding segregation. Kronacher (4) implied that the character was transmitted pure after hybridization, for he says:

Der Züchter v. Dunin-Kozicky liess im Jahre 1888 ein derartiges, gelegentlich erhaltenes Einhuferschwein (polnisches Landschwein) von einem Yorkshireeber decken und erhielt zur Hälfte (5 von 9) solche Einhufernachzucht, die ihr charakteristisches Merkmal rein Eitervererbte.

It is difficult to know whether Kronacher really means that these mule-foot hybrids gave no cloven-footed segregates or that the character when transmitted showed no contamination after the cross and was therefore "pure." Reference to the original source quoted by Kronacher leaves no doubt as to segregation, for von Dabrowa-Szremowicz (1) states explicitly that, in attempting to fix the mule-foot character, sporadic cases of cloven-foot crop out. He says:

Da bei den Schweinen es überhaupt schwer ist, eine einheitliche und gleichmässige Abart festzustellen, so treffen sich auch noch bei den meinigen vereinzelte Fälle mit gespaltenen Hufen.

It is clear, then, that this case agrees with both Spillman's and our own observations on dominance and with our observations on segregation.

The original mule-foot boar in these crosses was undoubtedly homozygous (MM) in the factor for syndactylism, for every one of his offspring, about 250, showed the mule-foot character. Six F_1 sows (Mm) were bred back to the cloven-foot Duroc-Jersey (mm), and each one gave both mule-foot and cloven-foot segregates. The total F_2 generation thus produced was 17 mule-foot + 25 cloven-foot, where theory calls for 21 of each kind as the most probable result. The deviation, 4, is no larger than one might reasonably expect as a fluctuation of sampling $\left(\frac{\text{deviation}}{\text{probable error}} = \frac{4}{2.19} = 1.83\right)$. If we add to these results those recorded by von Dabrowa-Szremowicz, we obtain 22 mule-foot + 29 cloven, where 25.5 is the most probable value. In this total, the calculated and observed results show even a closer agreement, for $\frac{\text{deviation}}{\text{probable error}} = \frac{3.5}{2.41} = 1.45$.

In experiments with the larger domestic mammals the usual apology for small numbers must be made, for they often obscure the real facts. In making our results a test against a monohybrid Mendelian hypothesis we must not overlook the fact that our data might also admit of a dihybrid interpretation with interaction of two factors to produce the mule-foot character. For example, if mule-foot were due to the interaction of X and Y, then the original mule-footed grandparent was XXYY and, mated to xxyy females, gave XxYy in the F_1 generation. Back-crossing to xxyy would thus be supposed to give:

$$\underbrace{\text{XxYy}}_{\text{25 per cent mule-foot}} + \underbrace{\text{Xxyy} + \text{xxYy} + \text{xxyy}}_{\text{75 per cent cloven-foot}}.$$

We observed a ratio of 17 mule-foot to 25 cloven-foot in the F_2 generation, while on this latter hypothesis the calculated results would be 10.5 to 31.5. The $\frac{\text{deviation}}{\text{error}} = \frac{6.5}{1.89} = 3.43$. The odds against deviations as wide or wider are about 45 to 1. But if we again add the results of von Dabrowa-Szremowicz to ours, the observed ratio is 22 to 29, where 12.75 to 38.25 is the calculated ratio. In these combined results the $\frac{\text{deviation}}{\text{error}} = \frac{9.25}{2.09} = 4.43$. The odds against deviations as wide or wider are now about 350 to 1. In both cases the monohybrid explanation is much more satisfactory. Furthermore, on a dihybrid hypothesis we should sometimes obtain mule-footed when F_2 cloven-footed segregates are mated together. To test this, such matings were made. Two of the three cloven-foot F_2 daughters of ♀ 2 (♀ 2e and ♀ 2f in Table II) were bred to a cloven-foot F_2 son of ♀ 3 (♂ 3f, Table II).[1] One F_2 ♀ gave 5 F_3 cloven-foot (4 ♂ ♂ + 1 ♀) and the other F_2 ♀ gave 13 F_3 cloven-foot (5 ♂ ♂ + 8 ♀ ♀). Therefore, a total of 18 F_3 cloven-foot was obtained from F_2 cloven-foot segregates bred *inter se*. In the F_3 generation two cloven-foot ♀ ♀ (♀ 2f-b and ♀ 2f-c) were mated to their cloven-foot brother, ♂ 2f-a, and gave 4 and 8 cloven-foot respectively. We may conclude that mule-foot and cloven-foot represent a single allelomorphic pair, in which the syndactylous form is dominant and the normal form is recessive, and that extracted recessives breed true.

As is common among mule-foot swine, the fused phalanges may separate along the line of fusion as the animal becomes older and heavier. This splitting was infrequent in the front feet, but was occasionally seen in the hind feet. There was never any difficulty in classifying the syndactylous and normal at the time of birth or when the animals were young, for syndactylism is a distinct discontinuous variation from normal. There is, however, some variation in syndactylism itself. Fusion may vary from complete, with no trace of separation on the hoof, to a less perfect fusion with two deep parallel lines of demarcation. The former condition is characteristic of the front feet, while the latter is the usual condition in the hind feet. In an examination of 17 F_2 mule-foot segregates, 14 showed complete fusion in the front feet, but 16 showed the deep lines of demarcation on the hind feet. The factor for syndactylism acts differently on the front and hind feet. (See Pl. 70.)

The relation of black to red in swine has never been quite clear. It is well known that Poland China or Berkshire mated to Duroc-Jersey usually produces a tortoise-shell type of red and black, but the amount of each color varies markedly. Sandy, yellow, cream, or even white may be substituted for red in such crosses, as shown by Severson (8). Wright (10) advanced a suggestive hypothesis that such a tortoise-shell type of sandy colored hog with black spots was selected in two directions to give the characteristic color of the Berkshire or Poland China, on the one

[1] The relationship of all animals recorded in this paper may be obtained from Table II, the original data.

hand, and Duroc-Jersey or Tamworth on the other. Selecting on the basis of minor factors for the extension of black and for the dilution of red to white gave the Berkshire color type, while selecting minor factors for the restriction of black and for the intensity of red gave the Duroc-Jersey type. In our crosses the self-black of the mule-foot does not act like the black of the Berkshire with its peculiar pattern, but whether this is due to a real difference in their genetic factors for black or is due to variable spotting factors in the Berkshire as compared with the self of the mule-foot remains to be shown. The six white points of the Berkshire may represent a highly selected spotting factor, or factors, with numerous modifiers. By crossing such Berkshires to Duroc-Jerseys one would expect to obtain a complex spotted hybrid. The mule-foot and the Duroc-Jersey are both self-colored and, as our experiments indicate, a cross between the two involves no striking spotting factors but shows clear-cut segregation between self-red and self-black. We may, therefore, regard black (B) as a dominant allelomorph to red (b) in our crosses.

The original mule-foot boar (BB) was mated to Duroc-Jerseys (bb) and gave about 250 F_1 hybrids (Bb) which were self-black. The 6 F_1 sows mated to a Duroc-Jersey boar gave 19 blacks to 23 reds in the F_2 generation, where 21 of each kind is the calculated ratio. The recessive F_2 red segregates gave 18 F_3 reds. The F_3 reds when mated *inter se* gave 12 F_4 reds. Extracted recessive reds, therefore, breed true. The total results indicate that black and red are allelomorphs in this cross in swine, black being dominant to red. In all of the foregoing discussion the term red includes red, yellow, lemon, and cream shades—that is, any form showing red pigment but no black.

In any wide cross between two distinct varieties like the Duroc-Jersey and mule-foot there are many factorial differences involved, and we are not surprised to find numerous new variations in the F_2 generation and subsequent hybrids which were not seen in the parents. Thus, we observed an occasional white spot on the feet or hoofs, white spot on the upper lip, animals with varying amounts of roan, more variation in size, and the like. Among the more striking variations seen in the F_2 generation were the grades of intensity and dilution of red pigment. Although red in the Duroc-Jersey varies somewhat, the red F_2 segregates varied much more than the original Duroc-Jersey parents. The black of the F_1 and F_2 hybrids, on the contrary, did not vary perceptibly. This seems to indicate that diluters of red may be carried by black swine but that such diluters do not affect black. In this cross the original black mule-foot sire evidently contributed diluters of red to the black F_1 hybrids; and such diluters segregated, giving more variability in red in the F_2 generation. We can hardly suppose that the Duroc-Jerseys contributed the factors for this dilution, because Duroc-Jerseys mated *inter se* do not show such dilute forms as we observed among our red segregates. Samples of hair from each individual were saved. Comparing all F_2 reds with each other, we classified these around four more or less arbitrary

modes—red, yellow, lemon, and cream, given in the order of most intense to most dilute. Those classified as "cream" were, when adults, a very light straw color, almost white. The 23 F_2 individuals were distributed as follows: 6 red, 9 yellow, 2 lemon, and 6 cream. It is not certain that yellow and lemon belong to two genetically distinct classes. There is little difference between them. If we group yellow and lemon together as an intermediate shade, the ratio of 6 intense, 11 intermediates, and 6 dilutes suggests a 1:2:1 ratio; but this is probably a coincidence, and we can not infer a single allelomorphic pair of factors for intensity and dilution with incomplete dominance, as later experiments will show. We do not know what the calculated ratio for the various shades of red in such an F_2 population should be, for we do not know the genetic constitution of each F_1 female or the Duroc-Jersey male with regard to these diluters of red. This one fact, however, is clear—there was marked segregation in shades of red in the F_2 generation. Plate 70 shows some of the variation in the intensity of red.

In order to test these dilute conditions, ♀ 2e, an F_2 yellow, and ♀ 2f, an F_2 lemon, were mated to ♂ 3f, an F_2 yellow. It was thought that if yellow and lemon were intermediate conditions between cream and red, then these matings would give a range of forms from red to cream. Female 2e gave 5 F_3 offspring classified as red. They were discarded, and unfortunately some doubt exists as to the exact shade of red. The shade of red deepens as the animals grow older. We are quite sure they were not cream, but they may have been either yellow or red. Some were a deeper, more intense color than either F_2 parent. Female 2f gave 13 F_3 young, of which 5 were cream and 8 were yellow. The creams when born were absolutely white, and a microscopic examination of their hair cleared in xylol and mounted in Canada balsam showed no pigment. Later in life they acquired some yellow pigment in the medulla of the hair but little or none in the cortex and gave the general appearance of a very light straw-color. The presence of red, yellow, and cream among the F_3 offspring from yellow parents suggested that yellow might after all be an intermediate condition and that a lighter shade like cream is recessive. We did not know at that time whether a single pair of factors with incomplete dominance was involved or whether there were a number of independent factor pairs for yellow, the cumulative effect of which gave the more intense shades

If a single alleomorphic pair with incomplete dominance were responsible, then all the offspring from the F_3 creams should have been cream. Three F_3 animals (♂ 2f-a, ♀ 2f-b, ♀ 2f-c) classified as cream (white at birth but very light straw-color when adults) were bred *inter se* to give the F_4 generation. However, the offspring from these creams were not all cream, for ♀ 2f-b produced 4 creams, but ♀ 2f-c gave 4 creams, 3 yellows, and 1 red. This hypothesis, therefore, becomes untenable. The difference between the creams and yellows or reds in this last litter, as in all others, was a distinct one, and there can be no question as to the

accuracy of classification. The fact that yellow may give red, yellow, and cream and that the cream-colored may give red, yellow, and cream leads us to believe that there is an interaction of factors producing intensity of red and that similar somatic creams are not necessarily of the same genetic constitution. The case appears much like the belt in the Hampshire, where either belted × belted or nonbelted × nonbelted may give both forms; or like purple and white aleurone in maize, where either white × white or purple × purple may give both forms. We may add that the adult creams can hardly be distinguished from Chester White or Yorkshire color. Under the microscope these creams show little or no pigment in the cortex of the hair but show yellow granules in the medulla. Some white hairs from the Berkshire and Chester White may also show yellow pigment. We have seen white hairs from the Berkshire which show yellow pigment in the medulla exactly like our creams.

The fact that red hair may be so diluted as to be almost if not quite indistinguishable from white hair suggests that the so-called white hair in some breeds may really be a very dilute red. Severson's experiments (*8*) show that Berkshire mated to Duroc-Jersey may give white and black spotted rather than the usual red or yellow and black. If the white hair of the Berkshire is really a dilute red, such a result would be expected in occasional matings of Berkshire to Duroc-Jerseys carrying recessive diluters; and there seems to be much evidence that Duroc-Jerseys carry recessive dilution factors, for much lighter animals than the standards require are known. Severson mated such a white and black hybrid back to a Berkshire and obtained some red and black offspring. Disregarding the black, this mating is like our matings of two creams which gave reds, and it thus adds weight to our hypothesis that the intenser shades, like red and yellow, are due to interaction of at least two pairs of independent factors; but the more dilute shades, like cream or white, are due to the absence of one or both interacting factors. That is, zygotes with both interacting factors A and B would be red or yellow, while zygotes with either A or B, or neither, would be cream or white. The fact that creams or whites form one distinct grade and yellow and red form another leads us to believe that the two groups are quite distinct. The slight variations in red and yellow or in the creams may be due to other minor factors. Summarizing, we may say that there are three sources of evidence which indicate that cream or white may be dilute red, that dilution and intensity are complex characters due to interaction of independent factors, and that the so-called white hair in some breeds is really a cream or very dilute red, as follows: (1) Yellow pigment was found in the medulla of the hair of our creams and in the white hair of Berkshires, (2) red offspring were derived from our creams mated *inter se*, and (3) red and black spotted offspring were derived from Severson's white and black spotted hybrid (from Duroc Jersey × Berkshire) mated to Berkshire.

SUMMARY

Syndactylism in swine is allelomorphic and dominant to normal cloven-foot, and black is allelomorphic and dominant to red. The two pairs of factors are evidently independent of each other.

The factor for syndactylism does not show quite the same effect on the front feet as on the hind feet, for the fusion is usually less complete in the latter.

The Duroc-Jersey and mule-foot are both self-colored in this cross and transmit no distinct spotting factors. We have concluded tentatively that the hybrids between Duroc-Jersey and Berkshire (or Poland China) are spotted because the latter transmit highly selected dominant spotting factors.

Intensity of red appears to be due to the interaction of independent factors which do not affect black. Dilution of red or yellow to cream or white takes place when either one or neither of the interacting factors is present. The so-called white hair of some breeds like the Berkshire and Poland China is really a very dilute red of genetic composition similar to our cream segregates.

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PLATE 70

The four types of F_2 segregates from a cross between mule-foot boar and Duroc-Jersey sows.

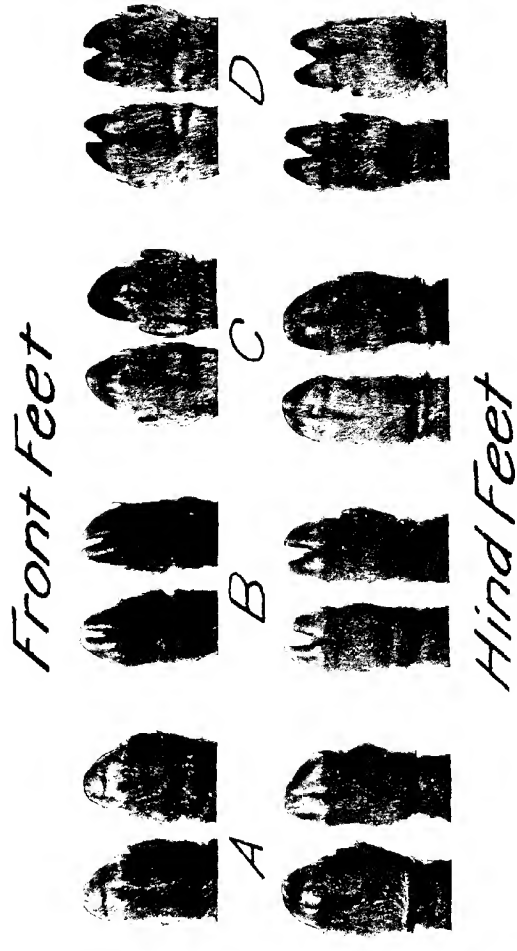
A.—Black mule-foot.

B.—Black cloven foot.

C.—Red mule-foot.

D.—Red cloven foot.

There is much variation in the intensity of red. The fusion in the hind feet is less pronounced than in the front feet.


Front Feet
Hind Feet
A
B
C
D

FOUR RHYNCHOPHORA ATTACKING CORN IN STORAGE

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INTRODUCTION

Of the numerous insect enemies of stored corn there are four belonging to the suborder Rhynchophora, or weevils, that are to a greater or less extent of economic importance in the United States. Of these four, one has received but little attention from economic entomologists, while of the remaining three much has been published, but comparatively little careful work has been done with the immature stages.

It is the purpose of this paper to present accurate drawings of the immature stages of these weevils, together with carefully prepared descriptions and keys, so that the various species may be readily distinguished in whatever stage they may be found.

The weevils under discussion represent two different families, Anthribidae and Curculionidae, and three different genera, Araecerus, Caulophilus, and Sitophilus, two of the weevils belonging to the last genus.

KEY TO ADULTS

a. Beak short and broad.

b. Robust beetle, antennæ inserted in small foveæ upon the upper surface of base of beak, last three segments of antennæ forming a loose club. *Araecerus fasciculatus* DeG.

bb. Slender, elongate beetle, antennæ inserted at middle of beak, last few joints forming a compact club..... *Caulophilus latinasus* Say.

aa. Beak elongate and slender.

c. Thorax with coarse, sparse, elongate punctures, wings lacking. *Sitophilus granarius* L.

cc. Thorax with coarse, deep, very dense punctures, wings present. *Sitophilus oryza* L.

KEY TO MATURE LARVÆ

a. Body slender, elongate, supplied with some or many long hairs, abdominal segments with hypopleurum not subdivided, mandibles armed dorsally with a pair of bristles set close together.

b. Larger, 4.5 to 6 mm. in length, body profusely covered with long hairs. *Araecerus fasciculatus* DeG.

bb. Smaller, 2 to 2.5 mm. in length, body sparsely provided with long hairs..... *Caulophilus latinasus* Say.

[1] The writer wishes to express his gratitude to Dr. Adam G. Böving, of the Bureau of Entomology, United States Department of Agriculture, for his kindness in extending much valuable aid and advice in the study of the larval forms and the preparation of the technical descriptions.

aa. Body short and stout, armed with but few small setæ, abdominal segments with hypopleurum subdivided into three lobes, mandibles armed dorsally with a pair of bristles set far apart.

c. First three abdominal segments only, above divided into three distinct areas, middle lobe of hypopleurum without seta....*Sitophilus oryza* L.

cc. First four abdominal segments above divided into three distinct areas, middle lobe of hypopleurum armed with a seta. *Sitophilus granarius* L.

KEY TO PUPAL STAGES

a. Antennæ not geniculate, folded over on dorsum.....*Araecerus fasciculatus* DeG.

aa. Antennæ geniculate.

b. Beak short and broad.....*Caulophilus latinasus* Say.

bb. Beak elongate and slender.

c. Inner wings rudimentary, almost completely concealed by elytra.....*Sitophilus granarius* L.

cc. Inner wings well developed, extending well beyond tips of elytra.....*Sitophilus oryza* L.

ARAECERUS FASCICULATUS [1]

SYNONYMY [2]

Araecerus fasciculatus DeG.

"DeGeer. *Ins. V, 1775. p. 276. t. 16. f. 2.*—Wollast. *Ann. Nat. Hist. V. 1870. p. 18.*—Lucas. *Ann. Fr. 1861. p. 399.*

cacao Fabr. *Syst. Ent. p. 64.*—Oliv. *Ent. IV. 80. p. 15. t. 2. f. 21. a-b.*

capillicornis Say. *Journ. Ac. Phil. V. 2. 1827. p. 249.*

moestus Lec. *Ann. Lyc. I. p. 172.*

cassiae Winthem. Dej. *Cat. 3. ed. p. 259.*

coffeae Fabr. *Syst. El. II. p. 411.*—Gylh. *Schh. Gen. Curc. I. p. 175*—Labr. et Imh. *Gen. Curc. I. nr. 55.*

crassicornis Fabr. *Ent. Syst. Suppl. p. 159; Syst. El. II. p. 399.*

griseus Steph. *Ill. Brit. IV. p. 211. t. 21. f. 2. (forte.)*

japonicus Thunb. *Nov. Act. Ups. VII, p. 122.*

perigrinus Herbst, *Käf. VII. p. 168. t. 106. f. 9.*

saltatorius Falderm. *in litt.*

var. *sambucinus* Boisd. *Voy. Astrol. II. p. 299 (forte.)*—MacLeay, *Dej. Cat. 3. ed. p. 259.*"

Araecerus fasciculatus (Pl. 71) was described in 1775 by DeGeer from Surinam. It is thought to have originated in India, but now it is cosmopolitan in distribution. This beetle, commonly known as the coffee-bean weevil, is robust, dark brown, and clothed with mottled light and dark brown pubescence. The beak is short and wide.

ADULT

Ovate, convex. Dark brown to black or piceous, clothed with yellowish and dark brown pubescence; intervals of elytra alternately vessellate with brown and yellowish; antennæ, tibiæ, and tarsi reddish brown, club fuscous; femora piceous at middle. Thorax very finely and exceedingly densely punctate. Elytra with rows of fine, close-set, feebly impressed punctures; intervals very finely and densely granulate-punctate. Length 2.5 to 4.5 mm.[3]

[1] Family Anthribidae, tribe Araecerini.

[2] GEMMINGER, M., and HAROLD, H. DE. CATALOGUS COLEOPTERORUM. v. 9, p. 2749. Monachii, 1872.

[3] BLATCHLEY, W. S., and LENG, C. W. RHYNCHOPHORA OR WEEVILS OF NORTH EASTERN AMERICA. p. 42. Indianapolis, Ind. 1916.

EGG

Egg shining, white, ovoid in shape; top broadly rounded, bottom slightly more pointed. Length about 0.56 mm., width 0.35 mm.

LARVA

Mature larva 4.5 to 6 mm. in length; white, footless, fleshy grub with body curved, wrinkled, and profusely covered with long hairs. Head very pale straw color; anterior margin and mandibles slightly darker. Head longer than broad, somewhat oblong in shape. Epicranial and frontal sutures faint and slightly lighter in color; there are also two longitudinal, light stripes rising from the frontal sutures and running to base of head. Frons almost triangular in shape; frons and epicranial lobes provided with numerous long hairs. Antenna small, situated at anterior corner of frons. Mandibles large, stout, triangular, with apex produced into an acute tooth; inner edge toward apex provided with two acute subapical teeth and above protractor with a large molas process or structure. Dorsal area of each mandible armed with a pair of stout bristle set close together. Eye represented by a well-defined black spot beneath the exoskeleton. Clypeus and labrum present, both broader than long and about equal in breadth. Labrum provided with four pairs of dorsal hairs and five pairs of short, thickened, marginal setæ; ventral surface of labrum with four small setæ. Maxillæ elongate, terminated by a 2-jointed palpus and a single setose lobe. Maxilla armed with numerous long hairs and a stout chitinized seta on palpifer just below the maxillary lobe. Stipes labii fused with the basal joint of the 2-jointed palps and bearing two setæ on each side. Ligula and lingua fused and marked by a seta on each side. Linguar region with numerous small asperities and a few setæ. Behind linguar region is a strong hypopharyngeal chitinization connected on each side with epicranium with well-developed hypopharyngeal bracon. Chitinization anteriorly provided with a cavity the bottom of which bears pointed processes. Posterior part of hypopharyngeal chitinization less heavily chitinized and limited by a chitinized frame which gradually continues over into floor of œsophagus. Mentum and submentum separated, mentum bearing two long hairs and submentum nine pairs of long hairs arranged in four groups of four each and a median pair.

Pronotum simple and not divided. Mesothoracic and metathoracic segments are above divided into three areas, representing praescutum, fused scuto-scutellar area, and postscutellar area; below and adjacent to epipleurum is alar area. Below ventrolateral suture are hypopleurum, coxal lobe, and eusternum, all well-defined and profusely provided with long hairs. Mesothoracic spiracle located on precpipleural lobe of mesothorax near prothorax; larger than abdominal spiracles and differing from them by being bifore whereas abdominal spiracles are monofore. Kidney-shaped air tubes pointing dorsad. Ten abdominal segments: Ninth, small; tenth, reduced; one to eight, each provided with monofore spiracles, that of eighth segment being located slightly more dorsad and with air tube pointing cephalad instead of dorsad. Praescutal and scutal areas of abdominal segments large and protuberant; scutal area, however, attenuating dorsad and not reaching the dorsal outline, scutellum and postscutellum flatter. Praescutum, scutum, and scutellum profusely armed with long hairs. Epipleural lobes bulging and prominent, also well supplied with long hairs.

Measurements of larval stages

STAGE.	WIDTH OF LARVAL HEAD.
1	0.22 mm.
2	.34 mm.
3	.58 mm.
4	.78 mm.
5	.90 mm.

PUPA

Pupa white when first formed, cast larval skin clinging tightly to last abdominal segments. Length 3.75 to 4 mm.; width 2 mm. Tips of elytra pointed and terminated with a long, chitinized hook nearly reaching seventh abdominal segment. Metathoracic tarsi extending well beyond tips of elytra. Head rounded, beak short and broad. Head profusely supplied with hairs. Antennæ nongeniculate, folded over on dorsum, tips nearly meeting on metanotum. Prothorax profusely supplied with long hairs, femora apically armed with several hairs. Mesonotum and metanotum each provided with two bunches or tufts of long hairs. Elytra armed with numerous hairs. Each abdominal segment is armed with two rows of dorsal, and numerous lateral, hairs. Seventh and eighth abdominal tergites apparently fused together; the ninth segment bears two large bilobed fleshy processes armed with numerous papillæ. The tenth segment is ventral to the ninth.

CAULOPHILUS LATINASUS [1]

SYNONYMY [2]

Caulophilus latinasus Say.

"*Rhyncholus latinasus*, Say, Descr. N. Am. Curc. p. 30 (1831) Complete Writings, I. p. 299 (nec Boheman).

Caulophilus latinasus, Lec. Proc. Am. Phil. Soc. xv. p. 340 (1876); Champ. Ent. Monthly Mag. xlv. p. 121.

Caulophilus sculpturatus, Woll. Ins. Mader. p. 315, t. 6. figg. 4–4 *a–c* (1854).

Cossonus pinguis, Horn, Proc. Am. Phil. Soc. xiii. p. 442 (1873). Cossonus picipennis, Sturm, in litt."

Caulophilus latinasus (Pl. 72) was described from Florida in 1831 by Thomas Say. This weevil is now widespread over the State of Florida and has been reported from South Carolina and Georgia. It is also known to occur in Jamaica, Porto Rico, Mexico, Guatemala, and Madeira. It is doubtless common throughout the islands of the West Indies and in the countries of Central and South America.

It is commonly known as the "broad-nosed grain weevil," and is a slender, elongate, reddish brown weevil with a short, broad beak. Technical descriptions of the adult and immature stages follow.

ADULT

Elongate, rather robust. Reddish brown or piceous, feebly shining. Beak longer than half the thorax, sparsely punctured, with a faint elongate fovea between the eyes. Thorax as broad as long, moderately constricted near apex, sides strongly curved, base slightly narrowed, feebly bisinuate; disk rather finely and evenly punctured, with a broad, faint impression on basal third. Elytra subcylindrical, not wider than middle of and more than twice as long as thorax, moderately convex; striæ deep, rather coarsely and closely punctured on basal half, more finely or obsoletely near apex, the seventh and eighth united behind the humerus as in Allomimus; intervals convex, indistinctly punctulate. Under surface sparsely punctured. Front tibiæ sinuate within.

Length, 3 mm.[3]

[1] Family Curculionidae, subfamily Cossoninae, tribe Cossonini.

[2] CHAMPION, G. C. RHYNCHOPHORA. CURCULIONIDAE. CURCULIONINAE (CONCLUDED) AND CALANDRINAE. *In* Biol. Cent.-Amer. INSECTA. COLEOPTERA. v. 4, pt. 7, p. 40. 1909–1910.

[3] BLATCHLEY, W. S., and LENG, C. W. OP. CIT., p. 535.

EGG

Egg opaque, shining white, bottom broadly rounded, top flattened and fitting into a translucent cap. Length, without cap, 0.45 to 0.47 mm.; width 0.27 to 0.32 mm.

LARVA

Mature larva 2 to 2.5 mm. in length, a white, footless, fleshy grub, with body curved and wrinkled. Head light brown or straw color, the anterior margin and mandibles a darker brown. Head about as broad as long, almost circular in form. Epicranial and frontal sutures distinct and light in color. There are also two oblique, longitudinal light stripes rising from the frontal sutures and coalescing with the epicranial suture near the base of the head. Frons subtriangular, with a distinct dark median line running from posterior angle to middle, and indicating carina. Frons provided with four pairs of large setæ, sutural margins each bearing one seta. Epicranial lobes each bearing the following setæ: One close to posterior angle of frons and located in the oblique, longitudinal stripe rising from the frontal suture, one small seta posterior to this and near occiput, two anterior to it on disk of epicranium, two opposite middle of frons, one opposite middle of mandible, one opposite hypostomal angle of mandible and one on hypostoma near base of mandible. Epistoma represented by thickened anterior margin of the front. Pleurostoma represented by somewhat darker, declivous area surrounding the mandibular foramen. Mandibles stout, triangular, with the apex produced into an acute apical tooth. Inner edge toward apex provided with a subapical tooth and a small medial tooth, no molar structure. Dorsal area of each mandible armed with a pair of stout bristles set close together. Eye represented by a well-defined black spot beneath exoskeleton. Clypeus broad at base, sides narrowing toward apical angles; distinctly broader but not as long as labrum. Epistomal margin provided with two fine hairs on each side. Labrum about as broad as long, rounded in front, provided with three pairs of large setæ and five pairs of short, thickened, marginal setæ.

Maxillæ terminated by a 2-jointed palpus and setose maxillary lobe. Maxillæ each provided with four setæ as follows: One on first segment of palpus, two on vaginant membrane between palpus and palpifer, and one stouter and larger one midway between palpus and cardo. The stipes labii enforced posteriorly by a median triangular chitinization bear 2-jointed palpi and a single pair of setæ. Ligula bearing four small setæ. Mentum and submentum fused and bearing three large setæ on each side.

Pronotum simple and undivided; praescutal and scuto-scutellar areas roughly indicated by rows of setæ. Mesothoracic and metathoracic segments divided above into two areas representing praescutum and scuto-scutellum; below and adjacent to epipleurum is the alar area. Below ventro-lateral suture are a well-defined hypopleurum, coxal lobe, and eusternum. The thoracic spiracle, located on the preepipleural lobe of mesothorax, is bifore, with the fingerlike air tubes pointing dorsad, and is somewhat larger than the abdominal spiracles. Ten abdominal segments; ninth small, tenth reduced. Each tergum of first eight abdominal segments divided above into three distinct areas, praescutum, scutum, and scutellum. Below and adjacent to epipleurum is the alar area. Abdominal segments provided with setæ as follows: Two on praescutum, five on scutellum, two on alar area, two on epipleurum, one on coxal lobe, and two on eusternum. Each of the first eight abdominal segments bears a bifore spiracle, that of the eighth being slightly larger than the rest.

Measurements of larval stages

STAGE.	WIDTH OF LARVAL HEAD.
1	0.22 to 0.23 mm.
2	.33 to .38 mm.
3	.53 to .57 mm.

PUPA

Pupa white when first formed. Length 2.8 to 3 mm.; width about 1.3 mm. Tips of elytra attaining the sixth abdominal segment, tips of metathoracic tarsi not extending beyond wing tips. Head rounded, beak short and broad. Head provided with two prominent spines towards vertex, two smaller ones on sides above eyes, a spine on each side of front between eyes, two pairs on beak between frontal ones and base of antenna, two pairs on beak between base of antenna and tip of beak, and four pairs of small setæ on tip of beak. Prothorax provided with two pairs of antero-marginal setigerous tubercules, one pair of antero-lateral, two pairs of postero-lateral, and four pairs of dorsal setigerous tubercules. Mesonotum and metanotum each provided with two pairs of spines. Abdomen with eight distinct dorsal tergites; dorsal area of each armed with two pairs of large spines; lateral area of each tergite armed with a spine at base of which is a small seta. Epipleural lobes each obscurely armed with one or two minute setæ. Ninth segment armed as usual with two prominent pleural spines.

SITOPHILUS ORYZA [1]

SYNONYMY [2]

Sitophilus oryza Linn. 1763.

"*oryzae* Linn. *Amoen. Ac. VI. 1763. p. 395.*—Oliv. *Ent. V. 83. p. 97. t. 7. f. 81. a–b.*—Gylh. *Schh. Gen. Curc. IV. p. 981.*—Scriba. *Stett. Zeit. 1857. p. 377.*—Kollar. *Sitzgsb. Wien. Ac. 1848. V. p. 3.*

frugilega Degeer. *Mem. V. p. 273.*

granaria Stroem. *Dansk. Vid. Selsk. Skrift., II. p. 56.*

quadriguttata Montrouz. *Ann. Fr. 1860. p. 910.*"

Var. *zea-mais* Motsch. Etudes Ent. IV, p. 77 (1855); Casey, Ann. N. Y. Acad. Sci. VI, p. 686.

Sitophilus oryza (Pl. 73) was described in 1763 by Linnaeus. It is thought to have originated in India, but it is now cosmopolitan in distribution. It is the predominant species of the grain weevils in the southern States of North America, where it is known as the "black or rice weevil." It is easily the commonest and most destructive grain weevil in the United States.

It closely resembles *Sitophilus granarius* in form but is readily distinguished by the presence of wings and the different punctuation of the thorax. Technical descriptions of the adult and immature stages follow.

ADULT

Reddish brown to piceous, opaque, elytra frequently with four rufous spots. Beak slender, cylindrical, three-fourths as long as thorax, at base slightly dilated, above with four rows of rather coarse punctures and with a slight fovea between the eyes. Thorax longer than wide, constricted near apex, sides feebly curved, gradually divergent to base; disc densely, deeply, and coarsely punctured. Elytra oblong, slightly narrowed at tip, deeply striate, striæ very coarsely and closely punctured; intervals slightly convex, narrow, the sutural with a row of coarse punctures; each puncture, both of thorax and elytra, bearing a very short yellowish seta. Beneath very densely and coarsely punctured.

Length 2.1 to 2.8 mm.[3]

[1] Family Curculionidae, subfamily Calandrinae.

[2] GEMMINGER, M., and HAROLD, B. DE. OP. CIT., V. 8, p. 2653. 1871.

[3] BLATCHLEY, W. S., and LENG, C. W. OP. CIT., p. 575.

EGG

Egg opaque, shining white, ovoid to pear-shaped in form, widest below middle, bottom broadly rounded, neck narrowing sharply toward top which is somewhat flat and bears a small rounded protuberance that fits into a cap or plug that cements the egg into place. Length 0.65 to 0.70 mm., width 0.28 to 0.29 mm.

LARVA

Mature larva 2.5 to 3 mm. in length, a pearly white, fleshy grub; very thick-bodied, ventral outline being approximately straight while dorsal outline is almost semicircular. Head light brown in color, anterior margin and mandibles much darker. Head longer than broad and somewhat wedge-shaped, sides broadly rounded from middle to apex, which is slightly angular. Sides nearly straight from middle to anterior angles, lateral area with an oblique, longitudinal, lighter stripe or area. Epicranial and frontal sutures distinct and light in color; also two oblique, longitudinal, light stripes rising from the frontal sutures and coalescing with the epicranial suture near base of head. Frons subtriangular with a distinct, dark median line indicating carina, running from posterior angle to beyond middle. Sutural margins irregular or sinuate. Frons provided with five pairs of large setæ, sutural margins each bearing a large seta. Each epicranial lobe with the following setæ: One close to posterior angle of frons and located within oblique longitudinal stripe rising from frontal suture, one very small seta posterior to this and near occiput, two anterior to it on disk of epicranium, two opposite middle of frons, one opposite middle of mandible, one opposite hypostomal angle of mandible, and one on hypostoma near base of mandible. Epistoma represented by thickened anterior margin of front, distinctly darker in color, with anterior margin declivous and slightly curving and lateral angles slightly produced and elevated where they support dorsal articulation of mandibles. Pleurostoma represented by darker declivous area surrounding mandibular foramen. Mandibles stout, triangular, with apex produced into a broad apical tooth; inner edge toward apex provided with a subapical tooth and a small medial tooth; no molar part. Dorsal area of mandible provided with a pair of stout bristles set apart. Eye represented by a well-defined black spot beneath exoskeleton. Clypeus attached in front of frons and broadly transverse; broad at base, sides narrowing toward apical angles, slightly longer and broader than labrum, and bearing on epistomal margin two fine setæ on each side. Labrum distinctly broader than long with two small lateral and a larger rounded median lobe. Labrum provided with six large setæ behind middle, two marginal, short, thickened setæ on each of lateral lobes, and six similar marginal setæ on median lobe.

Maxilla with cardo present and distinct, stipes not divided into stipes proper, subgalea, and palpifer, but one continuous piece with the anterior inner angle produced into a single setose lobe. Palpus 2-jointed, bearing a single seta near apex of first segment. Three other setæ found on maxilla, two located on vaginant membrane between palpus and palpifer and one stouter and longer midway between palpus and cardo. No articulating maxillary area between maxilla and mental-submental region. Labium with submentum and mentum fused and represented by a broad lobe bearing three pairs of stout setæ. Stipes labii posteriorly enforced by a median, triangular chitinization, the anterior median section produced anteriorly between the palpi into a small lobe-like ligula which is fused with the lingua. Each stipes labii bears a single seta. Short, conical, 2-jointed palpi situated on anterior angles of stipites. Ligula bearing four small setæ. Prothorax not divided dorsally, but two areas, praescutal and scuto-scutellar, roughly indicated by rows of setæ. Mesothoracic and metathoracic segments divided above into two distinct areas, the anterior of which represents praescutum, and the posterior the scuto-scutellum and alar area. The thoracic spiracle is located on a lobe pushed into prothorax from epipleurum of mesothorax.

It is bifore, elongate, larger than abdominal spiracles and placed with the fingerlike air tubes pointing dorsad. Ten abdominal segments; ninth small, tenth reduced. Each tergum of first three abdominal segments divided above into three distinct areas, praescutum, scutum, and scutellum. Each tergum of fourth to eighth abdominal segments divided above into only two areas, first containing praescutal and scutal elements, second representing scutellum. Below these two areas and adjacent to the epipleurum is the alar area. Abdominal spiracles placed anteriorly and in a small separate corner piece, probably of alar area; spiracles bifore and found on abdominal segments one to eight, that on the eighth being located slightly more dorsad than the rest. Below a very indistinct and abrupt dorso-lateral suture and above a well-defined ventro-lateral suture is a large, not subdivided epipleurum. The abdominal epipleura are located considerably higher than the thoracic lobes. Below ventro-lateral suture is hypopleurum subdivided into three lobes, one directly under the other. Below hypopleurum is coxal lobe and below that sternum, consisting of eusternum and a posterior triangular area representing parasternum or parasternum fused with sternellum. Abdominal segments provided with setæ as follows: One on praescutum, a long and two short ones on scutellum, two on alar area located just above spiracle, two on epipleurum, one on coxal lobe, and two on eusternum. One of the setæ on the scutellum is usually missing on abdominal segments five to nine.

Measurements of larval stages

STAGE.	WIDTH OF LARVAL HEAD.
1	0.22 mm.
2	.32 mm.
3	.48 mm.
4	.64 mm.

PUPA

Pupa uniformly pearly white when first formed. Length 3.75 to 4 mm.; width about 1.75 mm. Tips of wing pads attaining seventh abdominal segment, tips of metathoracic tarsi extending beyond tips of inner wings. Head rounded, beak elongate and slender. Head with two prominent spines toward vertex, a group of two small spines and two spinules on each side above eyes, two pairs of small spines near anterior margin and one on each side of front between eyes. Three pairs of spines on beak between frontal ones and base of antenna, a pair of small ones on beak midway between base of antenna and tip of beak, a pair on sides of beak between latter pair and tip of beak, and two pairs of smaller ones on tip of beak. Prothorax provided with one pair of antero-marginal setigerous tubercules, one pair of antero-lateral, two pairs of medio-lateral, and four pairs of dorsal setigerous tubercules. Mesonotum and metanotum each provided with three pairs of spines. Abdomen has seven distinct dorsal tergites, the seventh being much larger than the rest, dorsal area of each armed with a pair of large and a pair of smaller spines. Lateral area of each tergite armed with a spine at base of which is a small seta. Epipleural lobes are each armed with two minute spines. Ninth segment is as usual armed with two prominent pleural spines.

SITOPHILUS GRANARIUS

SYNONYMY [1]

Sitophilus granarius Linn. 1758.
granarius "Linn. *Syst. Nat. Ed.* X. p. 378.—Panz. *Fn. Germ. 17. 11.*—Gylh. *Schh. Gen. Curc. IV. p. 977.*—Jacq. Duv. *Gen. Col. Curc. 1854. t. 29. f. 140.*—Frisch. *Beschr. All. Ins. 1720. II. p. 36. t. 8.*
pulicaria Panz. *ed. Voet. IV. p. 54. t. 37. f. 17.* (*forte.*)
segetis Linn. *l. c. p. 381.*
unicolor Marsh. *Ent. Brit. p. 275.*—Steph. *Ill. Brit. IV. p. 9.*"

Sitophilus granarius (Pl. 74) was described in 1758 by Linnaeus. It is thought to have originated in the regions of the Mediterranean, but is now widely distributed throughout the world. It occurs but seldom in the southern States of North America, preferring the cooler climate of the North.

It is a slender, cylindrical, chestnut-brown beetle with a slender, elongate beak. Technical descriptions of the adult and immature stages follow.

ADULT

Elongate-oblong, feebly convex. Chestnut brown to piceous, moderately shining. Beak two-thirds as long as thorax, slender, cylindrical, finely and sparsely punctate. Thorax sparsely punctate, punctures coarse and on the disc more or less fusiform. Elytra deeply striate, striæ punctured at bottom, not serrate; intervals smooth, alternately wider and more elevated, especially towards the base; the sutural with a row of elongate punctures. Pygidium coarsely cribate. Body beneath coarsely and less densely punctured than in *oryza*. Length 3 to 4 mm.[2]

EGG

Egg opaque, shining white, ovoid to pear-shaped in form, widest below middle, bottom broadly rounded, neck narrowing gradually toward top, which is somewhat flattened and bears a small rounded protuberance that fits into a cap or plug that cements the egg in place. Length 0.68 to 0.80 mm., width about 0.33 mm.

LARVA

Mature larva 2.5 to 2.75 mm. in length; a pearly white, footless grub, fleshy and very thick-bodied, ventral outline being approximately straight while dorsal outline is almost semicircular. Head and appendages of head similar in every respect to those of *Sitophilus oryza*. Thoracic segments similar in external appearance to those of *S. oryza*. The abdominal segments are similar in form to those of *S. oryza* with the following exceptions which afford the best characters for distinguishing between larvæ of these two species: First four abdominal segments divided above into three distinct areas, praescutum, scutum, and scutellum, whereas in the larva of *S. oryza* the first three only of the abdominal segments are so divided. Middle lobe of the hypopleurum of the abdominal segments of *S. granarius* is provided with a seta. This seta lacking in larva of *S. oryza*.

[1] GEMMINGER, M., and HAROLD, B. DE. OP. CIT., V 8. p. 2653. 1871.
[2] BLATCHLEY, W. S., and LENG, C. W. OP. CIT., p. 574.

Measurements of larval stages

STAGE.	WIDTH OF LARVAL HEAD.
1	0.25 to 0.26 mm.
2	.36 to .37 mm.
3	.47 to .48 mm.
4	.61 to .65 mm.

PUPA

Uniformly white when first formed; length 3.75 to 4.25 mm., width 1.75 mm. Tips of elytra attaining fifth abdominal segment, inner wings rudimentary and almost completely concealed by elytra. Tips of metathoracic tarsi extending beyond tips of elytra. Head rounded, beak elongate. Head has two prominent spines toward vertex, a group of two small spines and two spinules on each side above eyes, two pairs of small spines near anterior margin and one on each side of front between eyes, three pairs of spines on beak between frontal ones and base of antenna, a pair of small ones on beak midway between base of antenna and tip of beak, a pair on sides of beak between latter pair and tip of beak, and two pairs of minute spines on tip of beak. Prothorax provided with one pair of antero-marginal setigerous tubercules, one pair of antero-lateral, two pairs of medio-lateral, and four pairs of dorsal setigerous tubercules; also a pair of minute medio-lateral ventral spines. Mesonotum and metanotum normally each provided with three pairs of spines; one or more pairs often missing. Abdomen with seven distinct dorsal tergites, the seventh being much larger than rest. Dorsal area of each armed with a pair of large spines and a pair of smaller ones. Lateral area of each tergite armed with a spine, at base of which is a small seta. Epipleural lobes each obscurely armed with two minute setæ. Ninth segment armed as usual with two prominent pleural spines.

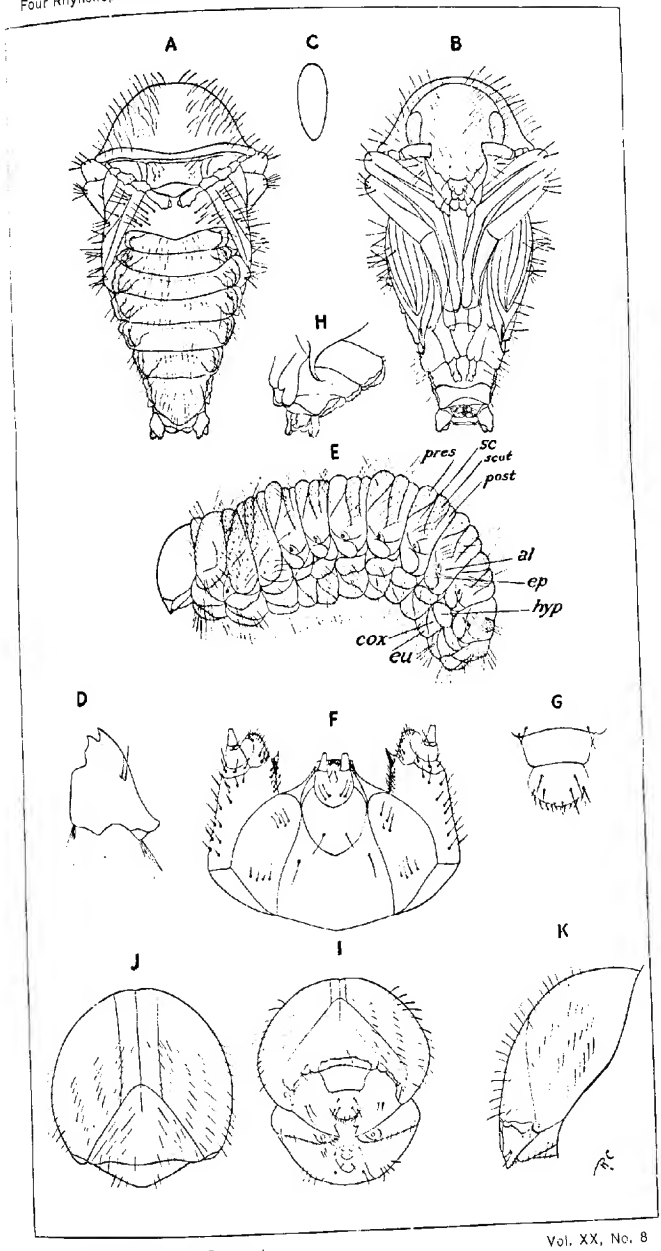
PLATE 71

Araecerus fasciculatus:

A.—Pupa, dorsal view.
B.—Pupa, front view.
C.—Egg.
D.—Mandible.
E.—Mature larva.
F.—Ventral view of head.
G.—Labium and clypeus.
H.—Pupa, lateral view.
I.—Head, face view.
J.—Head, dorsal view.
K.—Head, lateral view.

Key to larval parts

al=alar area.
cox=coxal lobe.
dlsut=dorso-lateral suture.
ep=epipleurum.
eu=eusternum.
hvp=hypopleurum.
par=parasternum.
post=postscutellum.
pres=praescutum.
sc=scutum.
scut=scutellum.
vlsut=ventro-lateral suture.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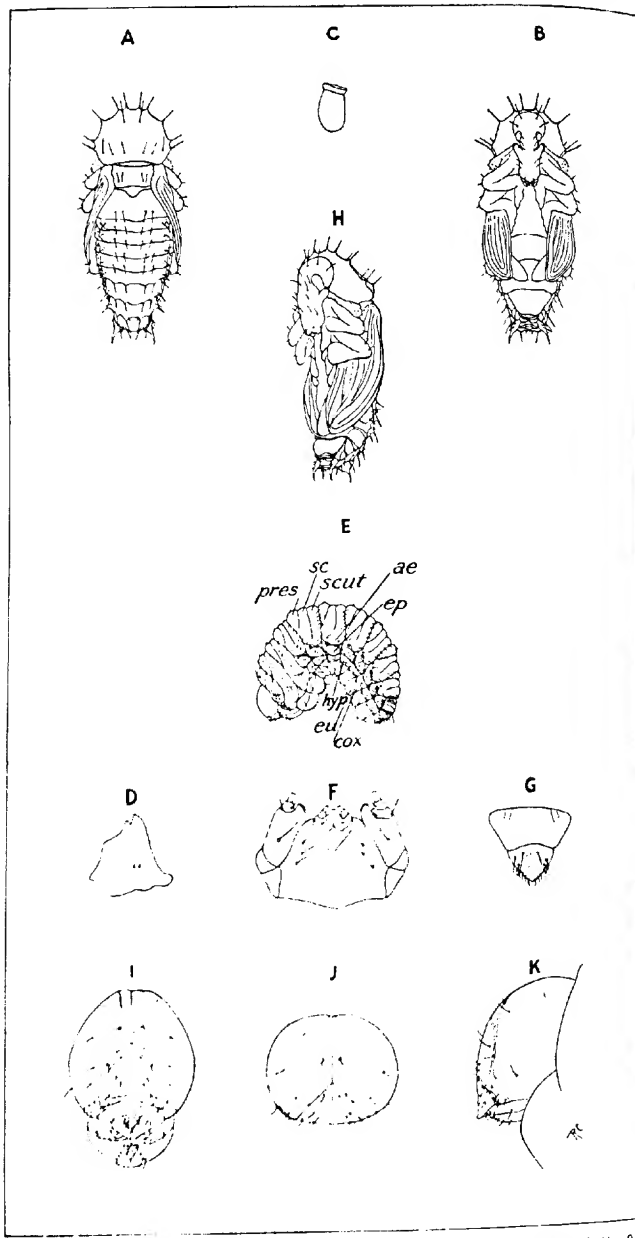
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PLATE 72

Caulophilus latinasus:

A.—Pupa, dorsal view.
B.—Pupa, front view.
C.—Egg.
D.—Mandible.
E.—Mature larva.
F.—Ventral view of head.
G.—Labium and clypeus.
H.—Pupa, lateral view.
I.—Head, face view.
J.—Head, dorsal view.
K.—Head, lateral view.

Key to larval parts

al=alar area.
cox=coxal lobe.
dlsut=dorso-lateral suture.
ep=epipleurum.
eu=eusternum.
hyp=hypopleurum.
par=parasternum.
post=postscutellum.
pres=praescutum.
sc=scutum.
scut=scutellum.
vlsut=ventro-lateral suture.

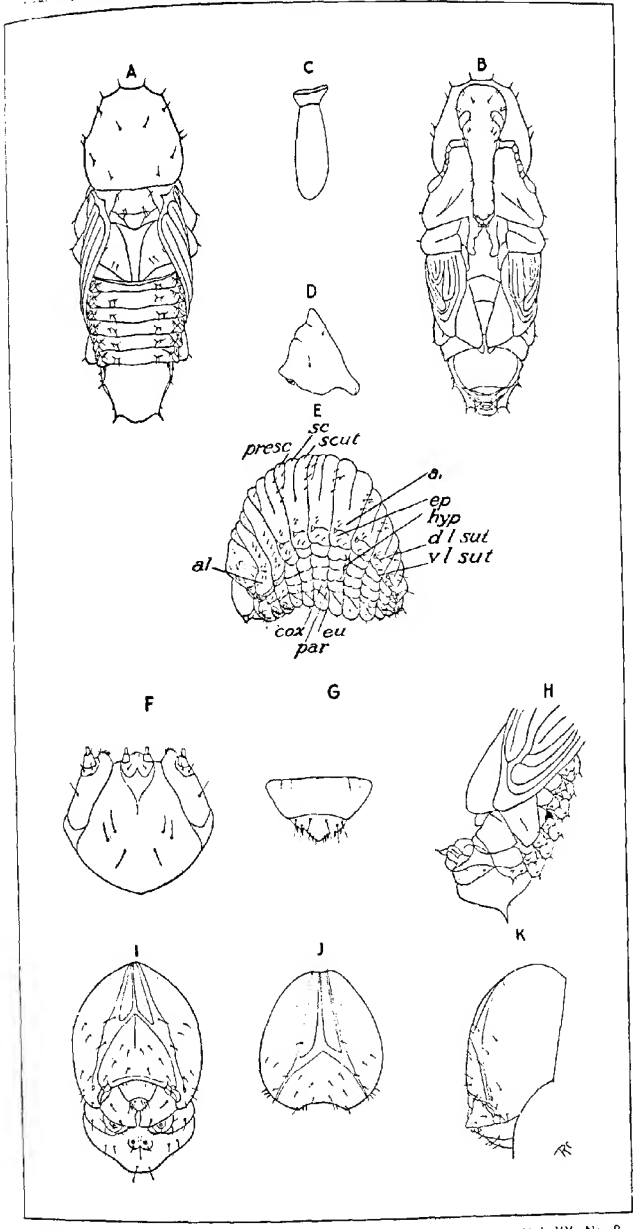
PLATE 73

Sitophilus oryza:

A.—Pupa, dorsal view.
B.—Pupa, front view.
C.—Egg.
D.—Mandible.
E.—Mature larva.
F.—Ventral view of head.
G.—Labium and clypeus.
H.—Pupa, lateral view.
I.—Head, face view.
J.—Head, dorsal view.
K.—Head, lateral view.

Key to larval parts

al=alar area.
cox=coxal lobe.
dlsut=dorso-lateral suture.
ep=epipleurum.
eu=eusternum.
hyp=hypopleurum.
par=parasternum.
post=postscutellum.
pres=praescutum.
sc=scutum.
scut=scutellum.
vlsut=ventro-lateral suture.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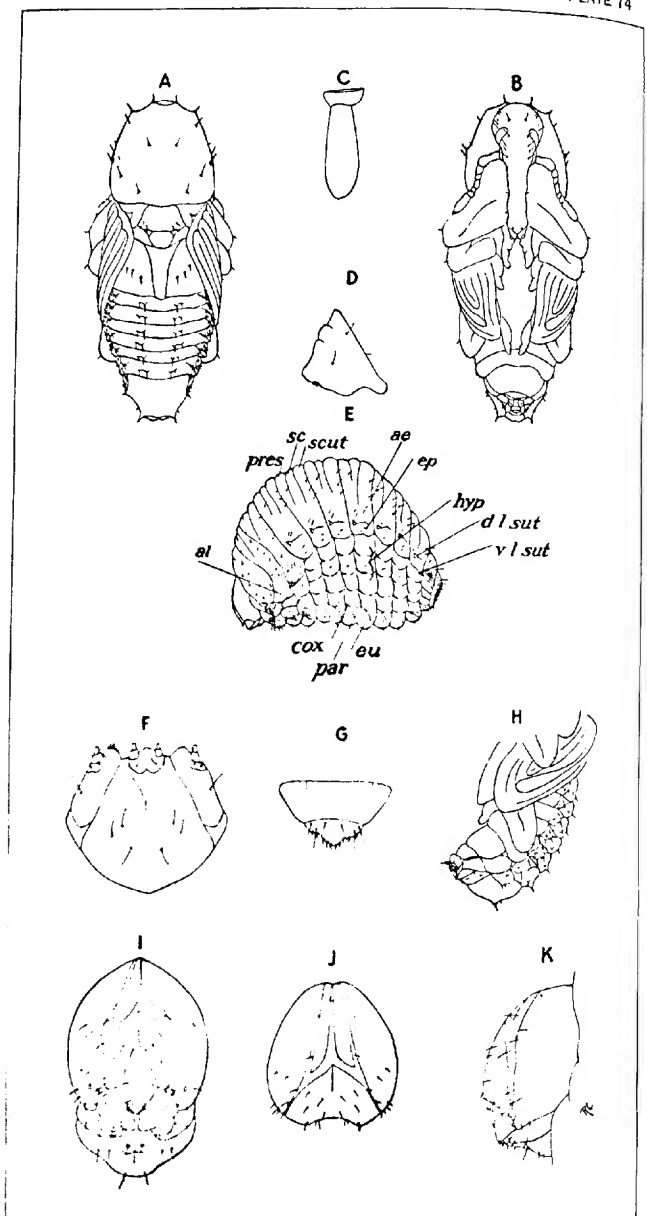
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PLATE 74

Sitophilus granarius:

A.—Pupa, dorsal view.
B.—Pupa, front view.
C.—Egg.
D.—Mandible.
E.—Mature larva.
F.—Ventral view of head.
G.—Labium and clypeus.
H.—Pupa, lateral view.
I.—Head, face view.
J.—Head, dorsal view.
K.—Head, lateral view.

Key to larval parts

al=alar area.
cox=coxal lobe.
dlsut=dorso-lateral suture.
ep=epipleurum.
eu=eusternum.
hyp=hypopleurum.
par=parasternum.
post=postscuttellum.
pres=praescutum.
sc=scutum.
scut=scutellum.
vlsut=ventro-lateral suture.

CONCENTRATION OF POTASSIUM IN ORTHOCLASE SOLUTIONS NOT A MEASURE OF ITS AVAILABILITY TO WHEAT SEEDLINGS

By J. F. BREAZEALE, *Associate Biochemist*, and LYMAN J. BRIGGS, *Physicist in Charge, Office of Biophysical Investigations, Bureau of Plant Industry, United States Department of Agriculture*

The object of the experiments described in this paper was to determine the availability of the potassium in solution of orthoclase by growing wheat seedlings in aqueous orthoclase solutions, analyzing the seedlings for potassium, and comparing the results with those obtained from suitable controls. The results show that the potassium present in solutions of orthoclase is not appreciably absorbed by young wheat plants. The conclusion is reached that potassium may be present in soil solutions in such combination with other elements that it is not available to plants.

The orthoclase used in our experiments was obtained near Riverside, Calif., and contained a total of 12.5 per cent of potassium oxid (K_2O). It was ground to pass a 60-mesh sieve. Different samples when brought into equilibrium with water and analyzed[1] contained from 2 to 9 parts per million of soluble potassium, the saturation concentration not being definite. There was, however, always some potassium present in the aqueous solutions, the average concentration being about 4 parts of potassium oxid per million of solvent.

The wheat was germinated on perforated aluminum disks floated on water. When the plumules were about ½ inch long the seedlings were transferred to other aluminum disks in the pans containing the culture solutions. This early transfer prevents the young seedling plants from absorbing the potash which exudes form unsprouted seeds.

The method of experimentation was, in general, to compare the potassium content of wheat seedlings grown in orthoclase solutions with that of similar seedlings grown in distilled water or other suitable control solution free from potassium.

SOLUBLE POTASSIUM IN ORTHOCLASE NOT AVAILABLE TO WHEAT SEEDLINGS

Wheat cultures were grown in orthoclase solution with and without the addition of gypsum and were compared with cultures grown in distilled water alone and in distilled water to which gypsum had been added. (See Table I, series a.) Although the orthoclase solutions were known

[1] The J. Lawrence Smith method was used in the analysis.

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from analyses to contain potassium, it will be noted that the wheat seedlings were unable to absorb any of it. This is of special interest, since the avidity of wheat seedlings for potassium is very marked.

The culture solutions in series b, Table I, included a control of distilled water (No. 1), 40 gm. of finely ground orthoclase in 2,500 cc. of distilled water (No. 3), and potassium chlorid solution containing 4 parts per million of potassium oxid (No. 5). Culture solutions Nos. 2, 4, and 6 were similar to No. 1, 3, and 5, respectively, except that gypsum was added to each in excess, so that it would always be present in the solid phase. To each of the six cultures were added also 50 parts per million of nitrate (NO_3) as sodium nitrate and 50 parts per million of phosphoric acid (P_2O_5) as sodium phosphate. Each solution, except those in which orthoclase was present in the solid phase, was changed twice daily in order to insure uniformity in concentration and freedom from bacterial disturbances. The wheat seedlings were grown in these culture solutions for 10 days. The analyses of the plants indicated, as before, that the wheat seedlings were unable to remove potassium from the orthoclase solutions. This was not due, however, to the diluteness of the solution, for in culture solutions containing only 4 parts per million of potash as potassium chlorid the plants were able to more than double their potash content in 10 days. The addition of nitrogen and phosphoric acid to the solutions did not modify the nonavailability of the potassium in the orthoclase solutions.

In series c the cultures were maintained for 17 days, all solutions being changed daily. Nitrogen and phosphoric acid were added to one culture, the sodium base being omitted. The results again showed no marked absorption of potassium from the orthoclase solutions.

The plants in series d were grown for 15 days. The analyses, as in the preceding experiments, showed no appreciable absorption of potassium by plants grown in orthoclase solutions, but a marked absorption was observed by plants grown in solutions of potassium chlorid. The presence of gypsum or orthoclase in the potassium chlorid solutions did not modify the rate of absorption of potassium from these solutions by the wheat seedlings.

The results in Table I, taken as a whole, show that the potassium in orthoclase solutions is not absorbed in measurable quantity by the wheat seedlings. On the other hand, potassium in potassium-chlorid solutions of equivalent concentration is readily absorbed by the plants.

TABLE I.—*Relative availability of potassium in orthoclase solutions and in potassium-chlorid solutions*

Culture No.	Culture solution.	K_2O in solution.	Dry weight of plants.	K_2O in 100 plants.	K_2O increase over control.
		P. p. m.	*Gm.*	*Gm.*	*Per cent.*
1a	Control (distilled water)	0	1.51	0.0295	0
2a	Control with $CaSO_4$	0	1.53	.0281	− 4
3a	Orthoclase (solid phase present)	2 to 9	1.54	.0284	− 3
4a	Orthoclase with $CaSO_4$ (solid phases present)	2 to 9	1.58	.0272	− 13
1b	Control	0	1.36	.0365	0
2b	Control with $CaSO_4$	0	1.34	.0368	+ 1
3b	Orthoclase (solid phase present)	2 to 9	1.43	.0366	0
4b	Orthoclase with $CaSO_4$ (solid phases present)	2 to 9	1.45	.0372	+ 2
5b	K Cl	4	1.50	.0783	+114
6b	K Cl with $CaSo_4$	4	1.40	.0860	+136
1c	Control	0	3.68	.0310	0
2c	Orthoclase (solid phase present)	2 to 9	3.96	.0302	− 2
3c	Orthoclase with $CaSo_4$ (solid phases present)	2 to 9	3.68	.0345	+ 11
4c	Orthoclase with $CaCO_3$ (solid phases present)	2 to 9	3.92	.0341	+ 10
5c	Orthoclase with 50 p. p. m. NO_3 and 50 p. p. m. P_2O_5	2 to 9	3.64	.0341	+ 10
1d	Control	0	4.08	.0368	0
2d	Control with $CaSo_4$	0	4.48	.0395	+ 7
3d	Orthoclase (solid phase present), changed daily	2 to 9	4.30	.0457	+ 33
4d	Orthoclase and $CaSo_4$ (solid phases present), changed daily	2 to 9	4.50	.0411	+ 11
5d	Orthoclase (solid phase) and 4 p. p. m. K_2O as KCl, changed daily	6 to 13	4.50	.0978	+166
6d	KCl	4	4.45	.0947	+157
7d	KCl with $CaSo_4$	4	4.85	.1010	+175
8d	Orthoclase and KCl, changed once	6 to 13	4.20	.0683	+ 86
9d	Orthoclase, not changed	2 to 9	4.10	.0388	+ 5

AVAILABILITY OF POTASSIUM IN ORTHOCLASE SOLUTIONS NOT INCREASED BY LIME OR GYPSUM

The application of lime and gypsum to orthoclase-bearing soils has been considered by some workers as a means of increasing the availability of the potassium in such soils. The authors[1] found in an earlier investigation that the addition of lime or gypsum to orthoclase solutions containing the solid phase did not increase the concentration of the potassium in the solution. The data presented in Table I show that these substances also had no effect on the availability of the potassium in the orthoclase solution.

[1] BRIGGS, Lyman J., and BREAZEALE, J. F. AVAILABILITY OF POTASH IN CERTAIN ORTHOCLASE-BEARING SOILS AS AFFECTED BY LIME OR GYPSUM. *In* Jour. Agr. Research, v. 8, no. 1, p. 21–28. 1917.

AVAILABILITY OF THE POTASSIUM IN ORTHOCLASE SOLUTIONS NOT INCREASED BY BOILING THE SOLUTION

The effect of boiling an orthoclase solution on the subsequent availability of the potassium is shown in Table II. In this experiment the potassium content of the plants grown in the culture solution was compared with that of the original seed. The analyses show that within the errors of experiment the availability of the potassium was not modified by boiling the orthoclase solutions.

TABLE II.—*Effect of boiling orthoclase solutions on the availability of the soluble potassium*

Culture No.	Material analyzed.	K_2O in solution.	Dry weight of plants.	K_2O in 100 plants.	K_2O increase over control.
		P. p. m.	*Gm.*	*Gm.*	*Per cent*
1	Original seed			0. 0368	0
2	Seedlings grown in orthoclase solution (solid phase present)	2 to 9	4. 00	. 0386	+5
3	Seedlings grown in orthoclase solution (solid phase present), boiled	2 to 9	4. 28	. 0330	−8

AVAILABILITY OF POTASSIUM IN ORTHOCLASE SOLUTION NOT INCREASED BY PRESENCE OF CARBON DIOXID

Carbon dioxid is universally present in the soil solution. It is consequently desirable to determine whether the availability of the potassium in orthoclase may be measurably increased by the addition of carbon dioxid to the solution. A culture solution of orthoclase with the solid phase present was accordingly prepared, and a portion of this solution was saturated with carbon dioxid. Plants grown in the two solutions showed no difference in their potash content (Table III). It consequently appears that a weak acid, such as carbonic acid, in concentrations equivalent to those found in soil solutions, does not increase the availability of the potassium in orthoclase.

TABLE III.—*Effect of carbon dioxid on availability of potassium in orthoclase*

Culture No.	Culture solution.	K_2O in solution.	Dry weight of plants.	K_2O in 100 plants.	K_2O increase over control.
		P. p. m.	*Gm.*	*Gm*	*Per cent.*
1	Orthoclase (solid phase present)	2 to 9	1. 92	0. 0284	0
2	Orthoclase (solid phase present) saturated with CO_2	2 to 9	1. 72	. 0284	0

SOLUBLE POTASSIUM IN ORTHOCLASE SOLUTIONS IS MADE AVAILABLE BY OXIDATION WITH ACIDS

To determine whether the soluble potassium in orthoclase could be available by oxidation with acids, the following experiment was carried out.

Finely ground orthoclase was added to about 100 liters of water, and this mixture was shaken at intervals until equilibrium was established and the maximum solubility of the potassium in the feldspar had been obtained.

One-half of this solution was filtered through a padded folded paper filter, and the clear solution, together with a few cubic centimeters of a mixture of hydrochloric and nitric acids, was then evaporated to dryness in Jena beakers. The excess of acids was driven off, and the solution was brought back to volume with purified distilled water. A little calcium carbonate ($CaCO_3$) was then added to insure alkalinity. Wheat seedlings were grown in such cultures for 14 days, the solutions being changed daily. The results are given in Table IV, series a.

TABLE IV.—*Effect of oxidation of soluble potassium in orthoclase on its availability*

Culture No.	Culture solution.	K_2O in solution.	Dry weight of plants.	K_2O in 100 plants.	K_2O increase over control.
		P. p. m.	*Gm.*	*Gm.*	*Per cent.*
1a	Control	0	2.42	0.0326	0
2a	Orthoclase (solid phase present)	2 to 9	2.52	.0349	+7
3a	Orthoclase solution filtered and evaporated with acids	4	2.88	.0722	+121
4a	KCl	5	2.48	.0620	+90
1b	Control	0	3.30	.0203	0
2b	Orthoclase (solid phase present)	2 to 9	2.66	.0180	+11
3b	Orthoclase solution filtered and evaporated with acids	4	3.30	.0357	+76
4b	KCl	5	3.36	.0815	.....

The wheat seedlings grown in orthoclase solutions in which the potassium compounds had been oxidized showed a total potash content at the end of the experiment about twice that of the plants grown in distilled water. On the other hand, the plants grown in the untreated orthoclase solution showed as before no gain in potash over the control.

A repetition of the experiment, Table IV, series 6, again showed a marked increase in the potash content of the plants grown in the solutions prepared from the oxidized solute. The orthoclase solution used in this series of experiments had stood in contact with the powdered mineral for about 2 months, being shaken at frequent intervals. The experiment extended over 19 days, the culture solutions being changed daily.

It is of interest to note that in the first series of experiments the potassium absorbed from the oxidized solute was equal to that absorbed from a potassium-chlorid solution containing 5 parts per million of potassium oxid. In the second series, the plants grown in the potassium-chlorid solution showed relatively a marked increase in their potassium content.

INCREASED AVAILABILITY OF POTASH IN OXIDIZED ORTHOCLASE SOLUTIONS NOT DUE TO ACTION OF ACIDS ON SUSPENDED COLLOIDS

The orthoclase solutions used in the preceding experiments contained some suspended colloidal material. It is therefore possible that the observed increase in the availbility of the potassium may have resulted from the direct action of the acids on the suspended colloids. To determine this point, a saturated solution of orthoclase was prepared and filtered through a Pasteur-Chamberland tube. A part of this filtrate was then treated with acids and evaporated to dryness, as described above, and subsequently diluted to its original volume and used as a culture solution. A portion of the original orthoclase solution which had not received the acid treatment was used as a control. The results of two experiments, made at different times, are given in Table V.

TABLE V.—*Effect of freeing culture solutions from colloids*

Culture No	Culture solution.	K_2O in 100 plants.	K_2O increase over control.
		Gm.	*Per cent.*
1a	Orthoclase solution, untreated with acids	0.0272	0
2a	Orthoclase solution, treated with acids	.0597	+120
1b	Orthoclase solution, untreated with acids	.0302	0
2b	Orthoclase solution, treated with acids	.0551	+83

The analyses of the plants show as before a marked gain in the potassium content of the plants grown in the acid-treated solutions. The colloids can not in this case be considered the source of the potash made available by the acid treatment, since the colloidal material was removed from the solution before the acids were added. We are consequently led to conclude that the orthoclase solutions contain potassium in true solution (as distinguished from colloidal suspension) and that the potassium is chemically combined in such a manner that it is not available to plants.

DISCUSSION

The failure of wheat seedlings to absorb the potassium found by analysis in orthoclase solutions suggests that the potassium is combined with other elements in a slightly soluble molecular complex. This is supported by the fact that the potassium may be made available by treatment with strong acids, which would result from the breaking

down of the complex. We may also assume that the solute complex is not dissociated, at least in such a way as to liberate potassium ions. For we can say with some assurance that free potassium ions would be absorbed by the wheat seedlings. We have evidence of this in the selective absorption exercised by wheat seedlings on potassium-chlorid solutions in which the potassium (either as $\overset{+}{K}$ or $\overset{+}{K}\overset{-}{OH}$) is selectively absorbed to such an extent that the culture solution becomes distinctly acid.

The effect of the oxidation of the solute complex in orthoclase solutions by hydrochloric and nitric acids is to reduce the potassium in the complex to potassium chlorid or potassium nitrate (KNO_3), in which form it dissociates and is readily absorbed.

The evidence presented in the case of orthoclase leads to the general statement that the concentration of a specific plant food element in the soil solution does not necessarily provide any measure of its availability. The question of availability must be referred to the plant itself, except perhaps in those cases in which the element in question is known to be ionized.

The results of our experiments have an immediate bearing on various investigations now in progress looking toward the utilization of orthoclase as a source of potash. It should be borne in mind that the application of finely ground orthoclase, without other treatment, probably does not contribute immediately to the available potash content of the soil.

CONCLUSIONS

From the experimental data presented the following conclusions are drawn, subject to the limitations imposed by the experimental error:

(1) The soluble potassium in aqueous solutions derived from finely ground orthoclase is not absorbed by wheat seedlings to a measurable degree.

(2) The availability of the potassium is not increased by the addition of lime, gypsum, or carbon dioxid to the solutions or by boiling the solutions.

(3) The soluble potassium in orthoclase solutions is made available by oxidizing the solute with hydrochloric and nitric acids.

(4) The increase in the availability following oxidation is not due to the action of the acids on suspended colloids, but is to be ascribed to the breaking down of the complex solute molecule.

(5) The concentration of a specific plant food element in the soil solution does not necessarily provide any measure of its availability. The question of availability must be referred to the plant itself.

COMPOSITION OF TUBERS, SKINS, AND SPROUTS OF THREE VARIETIES OF POTATOES

By F. C. Cook

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PREVIOUS INVESTIGATIONS

The composition of the potato undoubtedly varies with the soil and with the fertilizer used, as well as with other environmental and climatic conditions. Since the sprouts depend for their growth on the tubers, the composition of the tubers may influence that of the sprouts to no small extent.

The composition of tubers from different varieties of potato plants has not been investigated, nor has any extended study been made of the composition and growth changes of sprouts from the same or different varieties of tubers. Buckner (*3*),[1] who has reported analyses of sprouts skins, and tubers from one variety of potatoes for ash, phosphoric acid, magnesium oxid, calcium oxid, and silica dioxid found a relatively high percentage of ash in the sprouts.

The cause and regulation of rest periods in plants have been studied for years, several investigations having been devoted to the effect of various chemicals on tubers, with a view to shortening the rest period. Experiments at the Arizona Agricultural Experiment Station (*5*) have shown that ethyl bromid, carbon tetrachlorid, ammonia, gasoline, ethyl chlorid, and bromin are effective in bringing dormant tubers into activity—that is, in stimulating the buds. Seed tubers treated with manganese chlorid and ethyl ether showed no differences in the growth of foliage but exhibited a pronounced increase of tuber formation. Müller (*6*) claims to have shortened the rest period of tubers by storing them for one month at 0° C. Appleman (*1*) has found an increase of both total and reducing sugar in tubers stored at 0° C. According to this investigator, the carbohydrate transformation during the rest period depends entirely on the changing temperature. He has separated also the nitrogenous and the phosphorus compounds of tubers stored for various periods.

Schulze and Barbieri (*9*), in 1878, showed that potato sprouts contained nonprotein nitrogen in addition to protein nitrogen and found asparagin and solanin. It was shown that the potato contained 0.38 per cent nitrogen, practically one-half, or 0.18 per cent of which was in

[1] Reference is made by number (italic) to "Literature cited," p. 634-635.

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the form of protein nitrogen. Eighty-one per cent of the nitrogen in the tubers proved to be soluble—that is, appeared in the pressed juice of the potato. The sprouts contained 1.5 per cent of nitrogen on a dry basis. In 1880 these same investigators (*10*) isolated leucin and tyrosin from an alcoholic extract of potato sprouts. Osborne and Campbell (*7*) obtained a globulin called "tuberin," the properties of which they describe, and a small amount of another protein from potato. Sjollema and Rinkes (*11*) have studied the hydrolysis of potato protein. They precipitated the protein with a saturated sodium-chlorid solution, dissolved it in 10 per cent sodium chlorid, dialyzed it to remove the salt, and finally reprecipitated it with alcohol. The nitrogen content of the protein obtained was 14.9 per cent. Their investigation was divided as follows: (1) Estimation of the various diamino acids (Van Slyke method); (2) hydrolysis of protein by hydrofluoric acid; (3) estimation of different diamino acids (Kossel and Patten method); (4) estimation of momoamino nitrogen by Fisher's esterfication method; and (5) estimation of tyrosin. The result of their study of the hydrolysis of potato protein showed that 100 gm. contained nitrogenous substances distributed as follows:

	Gm.		Gm.
Ammonia	1.8	Alanin	4.9
Histidin	2.3	Leucin	12.2
Arginin	4.2	Valin	1.1
Lysin	3.3	Valin and alanin	8.2
Cystin	4.4	Valin and leucin	1.9
Glutaminic acid	4.6	Phenylalanin	3.9
Prolin	3.0	Tyrosin	4.3

Ramsay and Robertson (*8*) have reported data on the rate of assimilation of food from the soil by the potato plant and the relative proportion of each of the principal elements contained in the plants.

The fact that Bordeaux-sprayed potato plants in certain localities give larger yields of tubers than unsprayed plants has been established by a series of experiments extending over many seasons at the Vermont, Maine, and New York Agricultural Experiment Stations. Stewart, Eustace, and Sirrine (*12*), of the New York Experiment Station, reported several years ago that one lot of Bordeaux-sprayed tubers was higher in solids and starch than a corresponding lot of unsprayed tubers. Charles D. Woods, of the Maine Experiment Station, has reported similar findings (*13*). The writer has analyzed several samples of Bordeaux-sprayed and unsprayed tubers grown in Maine during the past three seasons generally finding a higher content of solids and nitrogen in the sprayed than in the unsprayed tubers.

OBJECT OF PRESENT INVESTIGATION

It was thought that some variation in the composition of sprouts of the same or different varieties of tubers might be found. It was also believed that the copper sprays used to control *Phytophthora infestans*, or late blight of the potato, might influence the time of sprouting—that is, increase or decrease the rest period compared with that of the unsprayed tubers—or that these sprays might modify the composition of the sprouts of the same varieties of tubers, just as copper sprays apparently influence the composition of the tubers. An investigation, therefore, was undertaken to determine, if possible, whether any of the changes just mentioned took place and to secure data on the chemical composition of sprouts, skins, and tubers.

EXPERIMENTAL WORK

DESCRIPTION OF SAMPLES

In the course of some tests on the influence of copper sprays on the control of *Phytophthora infestans*, or late blight of the potato plant, and on the yield of the tubers, several samples of Maine and Connecticut tubers dug in September, 1918, were stored in the laboratory at Washington, D. C., from October, 1918, until they were analyzed in the spring of 1919. Samples of Rural New Yorker (No. 12), Green Mountain (No. 15), and Irish Cobbler tubers (No. 9) from Maine, from selected hills where the vines were vigorous and healthy, as well as Green Mountain tubers (No. 3 and 6) from Connecticut, taken from portions of the plots which stayed green the longest were used for these tests. All the tubers were held in a dark closet at laboratory temperature (average 70° F.) from October, 1918, until February, April, or June, 1919. This relatively high temperature may have affected the composition of both tubers and sprouts. Several sprouts developed on each tuber, those on the Rural New Yorker appearing later than those on the Green Mountain and Irish Cobbler tubers. The sprouts of the Rural New Yorker tubers were short and thick, while those of the Green Mountain and Irish Cobbler tubers were comparatively long and branching.

METHODS OF ANALYSIS

At the time of analysis the sprouts were removed from the tubers and sifted to free them from adhering dirt. The tubers were washed and dried and then pared as thin as possible, a difficult matter because of their soft condition. The weights of the moist skins, tubers, and sprouts were taken separately. The tubers and the skins were then ground separately in a meat grinder, and each sample was well mixed and placed in a Mason jar with rubber and top. The sprouts were placed in a stoppered bottle. The analyses were begun as soon as possible. Solids, ash, phosphorus, and nitrogen determination were made on the moist samples,

the methods of the Association of Official Agricultural Chemists (2) being used.

Water extracts of the sprouts, skins, and tubers were prepared by macerating 50 gm. of the moist samples with a pestle in a mortar, then rinsing the material into a graduated flask with water, adding 10 cc. of toluene and making up to 500 cc. with water. The flasks were shaken each minute for the first 5 minutes and then every 15 minutes for the first hour, after which they stood overnight at room temperature. The next morning the liquid was removed with a pipette and filtered through glass wool and then through filter paper. The following determinations were made on the water extracts: (1) Soluble nitrogen, employing 25 cc.; (2) soluble phosphoric acid, employing 50 cc.; (3) ammonia nitrogen, employing 5 cc., by the aeration method of Folin (14) and nesslerizing the volatile nitrogen; (4) separation of nitrogenous compounds, employing 100 cc.

In making a separation of the nitrogenous compounds, 100 cc. of the solution were acidified and heated to boiling. The coagulable protein was removed first, then the remaining protein, by precipitation with dilute lead acetate solution. The lead was removed from the filtrate with hydrogen sulphid, the lead sulphid being filtered off and washed with a dilute solution of hydrochloric acid through which hydrogen sulphid had been passed. The solution containing the amino acids, amids, etc., was then made to volume, and the total nitrogen was determined in an aliquot. The largest portion of the filtrate was precipitated with phosphotungstic acid according to the Hausman method, and the nitrogen in the filtrate (monoamino and amid nitrogen) was determined. The nitrogen of the diamino acids and other bases was obtained by difference.

Copper was determined in certain of the samples by the colorimetric method, using potassium ferrocyanid and standard solutions of copper sulphate. This method, which has been shown to yield identical results with the electrolytic method, has the advantage of giving accurate results when minute amounts of copper are present and of being applicable when the electrolytic method is not.

RESULTS OF ANALYSIS

RELATIVE WEIGHTS OF SPROUTS AND TUBERS

The samples of sprouts, skins, and tubers numbered 1 to 3 and 4 to 6 (Table I) were of the Green Mountain variety. On February 1, 1919, the sprouts on these two sets of tubers constituted 4.6 per cent of the total moist weight of sprouts, skins, and tubers. Samples 1, 2, and 3 were from vines sprayed with 5-5-50 Bordeaux spray, while samples 4, 5, and 6 were from unsprayed vines. Samples 7, 8, and 9 (sprouts, skins, and tubers) were from Irish Cobbler plants. At the time of analysis,

April, 1919, the sprouts constituted 13.33 per cent of the total moist weight of sprouts, skins, and tubers. These plants had been sprayed with 5-5-50 Bordeaux.

The Rural New Yorker tubers (samples 10, 11, and 12) and the Green Mountain tubers (samples 13, 14, and 15) were grown at Foxcroft, Me., and had been sprayed with 5-5-50 Bordeaux spray. At the time of analysis, April, 1919, the sprouts of the Rural New Yorker tubers, a late variety, constituted 3.5 per cent and the Green Mountain sprouts 7.2 per cent of the total moist weight. These two varieties of tubers, dug from the same field late in September, 1918, were stored in the laboratory under identical conditions.

Samples of Green Mountain potatoes from Connecticut (samples 18 and 19), as well as the Irish Cobbler tubers grown in Maine (sample 21), were held at laboratory temperature until June, 1919, when the sprouts and tubers were analyzed separately. While the sprouts of the Irish Cobblers were large and fresh, those of the two samples of Green Mountain potatoes were partially dried and withered. No analyses of the skins were made for these three samples analyzed in June because of the difficulty of paring the soft tubers.

The variations in the percentage composition of sprouts obtained from tubers stored under identical conditions can be explained only on the basis of the presence in varying amounts of growth-promoting substances in the different varieties of tubers.

COMPOSITION OF SPROUTS AND TUBERS

The analytical data in Table I include the distribution of nitrogen in terms of total nitrogen. The total weight and percentage distribution of the ash, phosphoric acid, and nitrogen compounds present in the sprouts and tubers are given in Table II. Table III shows the ash, phosphoric acid, and nitrogen results on a water-free basis.

TABLE I.—*Analyses of tubers, skins, and sprouts on moist basis*

Source of potatoes and date of analysis.	Sample No.	Description of material.	Solids.	Ash.	P_2O_5.	Water-soluble P_2O_5.	Water-soluble P_2O_5 as total P_2O_5.	Total nitrogen.	Water-soluble nitrogen.	Coagulable nitrogen.	Nitrogen precipitated by lead acetate.	Non-protein nitrogen.	Amid and mono-amino nitrogen.	Diamino and other bases nitrogen.	Free NH_3 nitrogen.	Distribution of nitrogen in total nitrogen.				
																Water-soluble.	Protein.	Amid and mono-amino.	Diamino and other bases.	Free NH_3.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Connecticut, February, 1919.	1	Sprouts, Green Mountain, sprayed.	19.14	1.62	0.43	0.33	76.74	0.76	0.744	0.033	0.041	0.365	0.291	0.074	0.0041	57.89	51.97	38.29	9.74	0.54
	2	Skins, Green Mountain, sprayed.	26.38	1.45	.24	.14	58.33	.50	.36	.080	.012	.267	.203	.064	.0062	72.00	46.52	40.60	12.80	1.24
	3	Tubers, Green Mountain, sprayed.	24.29	1.15	.24	.14	58.33	.45	.42	.076	.020	.322	.239	.083	.0042	93.33	28.45	53.11	18.44	.93
	4	Sprouts, Green Mountain, unsprayed.	18.62	1.54	.43	.33	76.74	.74	.39	.033	.039	.329	.284	.045	.0041	52.70	55.54	38.38	6.08	.55
	5	Skins, Green Mountain, unsprayed.	23.43	1.44	.23	.14	60.87	.41	.31	.070	.014	.228	.200	.028	.0094	75.61	44.39	48.78	6.83	2.29
	6	Tubers, Green Mountain, unsprayed.	21.75	1.12	.21	.13	61.90	.40	.37	.063	.010	.291	.227	.064	.0036	92.50	27.25	56.75	16.00	.90
	7	Sprouts, Irish Cobbler, sprayed.	19.24	1.42	.33	.20	60.61	.73	.44	.059	.031	.358	.286	.072	.....	60.27	50.96	39.18	9.86	.....
	8	Skins, Irish Cobbler, sprayed.	23.54	1.52	.25	.14	56.00	.67	.44	.103	.013	.335	.176	.159	.0037	65.67	50.00	26.27	23.73	.55
	9	Tubers, Irish Cobbler, sprayed.	22.14	1.17	.24	.14	58.33	.63	.49	.076	.010	.388	.280	.108	.0028	77.78	38.41	44.44	17.14	.44
	10	Sprouts, Rural New Yorker, sprayed.	21.55	1.41	.37	.22	59.46	.75	.43	.038	.035	.359	.312	.047	.0040	57.33	52.13	41.60	6.27	.53
	11	Skins, Rural New Yorker, sprayed.	23.77	1.74	.27	.15	55.56	.43	.24	.056	.008	.187	.118	.069	.0032	55.81	56.51	27.44	16.05	.75
Maine, April, 1919.	12	Tubers, Rural New Yorker, sprayed.	24.01	1.20	.25	.12	48.00	.39	.30	.056	.008	.238	.164	.074	.0017	76.92	38.98	42.05	18.97	.44
	13	Sprouts, Green Mountain, sprayed.	18.57	1.38	.40	.25	62.50	.72	.44	.031	.034	.350	.302	.048	.0045	61.11	51.39	41.94	6.67	.63
	14	Skins, Green Mountain, sprayed.	21.97	1.52	.24	.14	58.33	.47	.25	.066	.011	.180	.134	.046	.0040	59.52	37.15	31.90	10.95	.95
	15	Tubers, Green Mountain, sprayed.	22.23	1.25	.23	.12	52.17	.35	.20	.068	.006	.208	.135	.073	.0025	82.86	40.57	38.57	20.86	.71
	16	Sprouts,[1] Green Mountain, sprayed.	22.93	1.58	.53	.36	67.92	1.27	.72	.029	.....	.61	.51	.10	.013	56.69	30.40	41.73	7.87	1.00

Maine and Connecticut, June, 1919...	17	Sprouts,[1] Green Mountain, unsprayed.	27.35	2.83	.50	.31	55.30	1.17	.65	.033	.....	.58	.49	.09	.005	55.56	50.43	41.89	7.69	.44
	18	Tubers,[1] Green Mountain, sprayed.	30.15	1.55	.25	.10	40.00	.70	.57	.042	.....	.50	.46	.04	.005	81.43	28.57	65.71	5.71	.14
	19	Tubers,[1] Green Mountain, unsprayed.	30.66	1.54	.23	.13	56.52	.65	.52	.042	.....	.46	.39	.07	.001	80.00	29.23	60.00	10.77	.15
	20	Sprouts,[2] Irish Cobbler, sprayed	28.32	2.41	.52	.25	48.08	1.10	.66	.049	.....	.54	.49	.05	.003	60.00	50.90	44.55	4.55	.30
	21	Tubers,[2] Irish Cobbler, sprayed	35.88	2.02	.28	.13	46.43	.74	.51	.049	.....	.41	.32	.09	.022	68.92	44.60	43.24	12.16	2.97

[1] Sprouts and tubers partly dried, analyzed in June; tubers from same lot as sample No. 3 and 6 analyzed in February.
[2] Sprouts fresh and tubers dried, analyzed in June; tubers from same lot as sample No. 9 analyzed in April.

TABLE 11.—*Weights, percentages, and chemical constituents of tubers, skins, and sprouts*

Sample No.	Description of material.	Moist weight.	Percentage weight of sprouts in total tubers.	Dry weight.	Ash.	Ash in solids.	P_2O_5.	P_2O_5 in solids.	P_2O_5 in ash.	Nitrogen.	Total nitrogen.	Total ash.	Total P_2O_5.	Copper, dry, basis.
		Gm.		*Gm.*	*Gm.*	*Per cent.*	*Gm.*	*Per cent.*	*Per cent.*	*Gm.*	*Per cent.*	*Per cent.*	*Per cent.*	*P. p. m.*
1	Sprouts, Green Mountain, sprayed	73	4.63	13.97	1.18	8.45	0.25	1.80	21.19	0.55	7.20	5.80	7.99	.....
4	Sprouts, Green Mountain, unsprayed	65.5	4.60	12.20	1.01	8.28	.21	1.72	20.80	.48	7.99	5.64	8.08	.....
7	Sprouts, Irish Cobbler, sprayed	231.5	13.33	44.54	3.29	7.39	.76	1.71	23.10	1.69	14.81	14.32	17.16	40
10	Sprouts, Rural New Yorker, sprayed	76	3.50	16.38	1.07	6.54	.28	1.71	26.17	.57	6.32	3.44	4.95	.....
13	Sprouts, Green Mountain, sprayed	101	7.19	18.76	1.39	7.41	.40	2.13	28.78	.73	13.04	7.36	11.63	41
2	Skins, Green Mountain, sprayed	632	.....	166.70	9.16	5.50	1.23	.74	13.43	3.13	.....	.....	.....	14
5	Skins, Green Mountain, unsprayed	531	.....	122.82	7.64	6.22	.98	.80	12.83	2.20	.....	.....	.....	21
8	Skins, Irish Cobbler, sprayed	592	.....	198.55	9.00	4.53	1.48	.70	16.44	3.97	.....	.....	.....	.....
11	Skins, Rural New Yorker, sprayed	660	.....	222.88	11.48	5.15	1.78	.80	15.51	2.84	.....	.....	.....	.....
14	Skins, Green Mountain, sprayed	443	.....	141.62	6.73	4.75	1.06	.75	15.75	1.86	.....	.....	.....	.....
3	Tubers, Green Mountain, sprayed	871	.....	211.56	10.02	4.74	1.65	.80	16.47	3.90	51.83	49.12	52.71	30
6	Tubers, Green Mountain, unsprayed	828	.....	180.09	9.27	5.15	1.41	.80	15.21	3.33	55.41	51.73	54.23	18
9	Tubers, Irish Cobbler, sprayed	913	.....	293.43	10.68	3.64	2.19	.75	20.51	5.75	50.39	46.39	49.44	.....
12	Tubers, Rural New Yorker, sprayed	1,439	.....	489.56	18.56	3.79	3.60	.74	19.39	5.61	62.20	59.66	63.60	.....
15	Tubers, Green Mountain, sprayed	861	.....	277.50	10.76	3.88	1.98	.71	18.40	3.01	53.75	56.99	57.59	.....
16	Sprouts, Green Mountain, sprayed	66.5	5.22	21.90	2.18	9.96	.35	1.60	16.06	.84	.....	.....	.....	.....
17	Sprouts, Green Mountain, unsprayed	56	5.04	15.32	1.58	10.31	.31	2.02	19.62	.66	.....	.....	.....	.....
20	Sprouts, Irish Cobbler, sprayed	80.5	17.06	22.80	1.94	8.50	.42	1.84	21.65	.89	.....	.....	.....	.....

TABLE III.—*Percentage of ash, phosphoric acid, and nitrogen in potato sprouts and tubers on water-free basis*

Source of potatoes and date of analysis.	Sample No.	Description of material.	Ash.	P_2O_5.	Nitrogen.	Condition of samples.
			Per cent.	*Per cent.*	*Per cent.*	
Connecticut, February, 1919	1	Sprouts, Green Mountain, sprayed	8.46	2.25	3.97	Sprouts fresh.
	4	Sprouts, Green Mountain, unsprayed	8.27	2.31	3.97	Do.
Maine, April, 1919	7	Sprouts, Irish Cobbler, sprayed	7.38	1.72	3.79	Do.
	12	Sprouts, Rural New Yorker, sprayed	6.54	1.72	3.48	Do.
	15	Sprouts, Green Mountain, sprayed	7.43	2.15	3.88	Do.
Connecticut, June, 1919	16	do	9.96	1.61	3.86	Sprouts withered.
Maine, June, 1919	20	Sprouts, Irish Cobbler, sprayed	8.51	1.84	3.88	Sprouts fresh.
Connecticut, February, 1919	3	Tubers, Green Mountain, sprayed	4.73	.98	1.85	Tubers soft.
	6	Tubers, Green Mountain, unsprayed	5.15	.97	1.84	Do.
Maine, April, 1919	9	Tubers, Irish cobbler, sprayed	3.64	.75	1.96	Do.
	13	Tubers, Rural New Yorker, sprayed	3.79	.74	1.15	Do.
	15	Tubers, Green Mountain, sprayed	3.88	.71	1.09	Do.
Connecticut, June, 1919	18	do	5.14	.83	2.32	Tubers withered and very soft.
Maine	19	Tubers, Green Mountain, unsprayed	5.02	.75	2.12	Do.
	21	Tubers, Irish Cobbler, unsprayed	5.63	.78	2.06	Do.

SOLIDS.—The solids of the young sprouts of the Green Mountain and Irish Cobbler varieties, samples 1, 4, 7, and 13, were exceedingly uniform, notwithstanding variations in the water content of the tubers. The moisture content of the sprouts seemed to be maintained at the expense of the tubers. The Rural New Yorker sprouts, sample 10, contained more solids than the other young sprouts. The older, partly dried sprouts, samples 16, 17, and 20, were highest in solids. The moisture content of the different varieties of tubers decreased with the period of standing in the laboratory.

ASH.—The important feature of the ash analyses was the high percentage of ash in the sprouts as compared with that in the tubers, made more evident on calculating the results to a moisture-free basis. The skins showed a higher percentage of ash than the tubers. The sprouts showed a selective action and withdrew the ash from the tubers in a greater proportion than it originally existed in them, so that the percentage of ash in the solids was nearly twice as high for the sprouts as for the tubers. A higher percentage of ash was found in the old than in the young sprouts and tubers.

PHOSPHORIC ACID (P_2O_5).—The phosphoric acid content of the sprouts was greater than that of the skins or tubers. In the solids of the sprouts it averaged 1.81 per cent and was less than 1 per cent for the skins and tubers. In the ash of the sprouts it varied from 20 to 30 per cent, while it was less than 20 per cent in the ash of the tubers and skins. From 60 to 76 per cent of the total phosphoric acid content of the young sprouts was water-soluble as compared with but 50 to 60 per cent of the phosphoric acid content of the skins and tubers. Somewhat less phosphoric acid was water-soluble in the older sprouts and tubers than in the younger samples.

NITROGEN.—The nitrogen content of the sprouts was apparently uniformly maintained. In the five samples of young sprouts examined (No. 1, 4, 7, 10, and 13) approximately 0.75 per cent of nitrogen was found. The older sprouts contained from 1.10 to 1.27 per cent nitrogen. The different varieties of sprouts showed a uniform percentage of the total nitrogen, both as protein nitrogen and as amid and monoamino nitrogen. The amid and monoamino nitrogen formed about 40 per cent and the diamino and other basic nitrogen formed less than 10 per cent of the total nitrogen of the sprouts. A higher percentage of amid and monoamino nitrogen was found in the older Green Mountain sprouts (samples 16 and 17) than in the younger Green Mountain sprouts (samples 1 and 4). The sprouts contained a lower percentage of total nitrogen in the form of coagulable protein but a higher percentage as total protein than did the tubers. The younger sprouts also contained a lower percentage of the total nitrogen as amid and monoamino nitrogen and of diamino and other base nitrogen than did the tubers. Based on the

percentage of total nitrogen, the younger tubers showed a greater content of water-soluble nitrogen than the older tubers. The samples of tubers analyzed in June contained a larger amount of total nitrogen than those analyzed earlier because of the added loss in water and the reduction in sugar and starch of the tubers caused by respiration.

AMMONIA.—The amount of free ammonia in the young sprouts was constant. More ammonia was found in the skins than in the tubers or sprouts. The older tubers apparently contained less ammonia than the younger ones.

COPPER.—All the samples tested showed copper, the sprouts containing somewhat more than the tubers or skin.

FACTORS WHICH MAY INFLUENCE THE COMPOSITION OF POTATO SPROUTS

Numerous factors may influence the composition of potato sprouts. Excluding the various physiological and other diseases, a few of these factors may be mentioned briefly.

VARIETY.—The analyses indicate that the composition of sprouts of the same age from the three different varieties of tubers examined was uniform. This was true in spite of the fact that the sprouts formed varying percentages of the total moist weight of tubers, skin, and sprouts and contained varying percentages of the total nitrogen, phosphoric acid, and ash.

BORDEAUX SPRAYING.—The results for solids and ash on the Green Mountain sprouts, skins, and tubers from sprayed vines (samples 1, 2, and 3) were slightly higher than those on sprouts, skins, and tubers from corresponding unsprayed vines (samples 4, 5, and 6). The distribution of the nitrogenous substances showed the same general trend in the two samples. The tubers from both the sprayed and unsprayed plants formed sprouts with equal rapidity, judging by the percentage weights of sprouts and tubers. The sprouts constituted 4.63 and 4.59 per cent of the total weight of sprouts, skins, and tubers of the two samples at the time of analysis. The percentages of nitrogen, phosphoric acid, and ash removed by the sprouts in the two cases were remarkably uniform. While it is impossible to draw a definite conclusion from the analyses of two samples only, the indication from these and other samples is that the percentage of solids and nitrogen is higher in the tubers from sprayed than in those from unsprayed potato vines.

SOIL, CLIMATE, AND FERTILIZER.—The potato is no exception to the well-known fact that soil, climate, fertilizer, and other factors often influence the composition of the crop. Calculated to a water-free basis (Table III), the Connecticut tubers and sprouts gave higher results for ash, phosphoric acid, and nitrogen than the other samples, suggesting an influence of soil and climate on the composition of the potato.

AGE AND GROWTH.—The age of the sprout apparently influences its composition. A higher percentage of solids and ash was found in the

older than in the younger sprouts. Many changes in the percentage of water-soluble to total phosphorus and in the distribution of the nitrogenous substances follow the growth of the sprouts. The principal period of growth of the sprouts under the conditions of this test occurred during the period up to March, or from 60 to 150 days after the tubers had been dug. From 150 days until the end of June, or 270 days after digging, the increase in weight of the sprouts was less. The sprouts of the Irish Cobbler tubers analyzed in June (sample 20) constituted 17 per cent, while those of the Green Mountain tubers (samples 16 and 17) constituted 5.5 per cent of the total weight of tubers and sprouts. The Cobbler is an early potato and the Green Mountain a late one. Both varieties had reached their limit of sprouting in June under the conditions of these tests. Apparently the growth-promoting principle is much more active or is present in larger amounts in the Irish Cobbler than in the Green Mountain and Rural New Yorkers.

DISTRIBUTION OF NITROGEN, PHOSPHORIC ACID, AND ASH IN SPROUTS, SKINS, AND TUBERS

The percentage distribution of nitrogen, phosphoric acid, and ash in sprouts, skins, and tubers depends upon the relative weights of sprouts and tubers. Although the sprouts of the Rural New Yorker tubers constituted 3.5 per cent of the total moist weight of tubers, skins, and sprouts, they contained 6.32 per cent of the total nitrogen. The sprouts of the Irish Cobbler on the same date constituted 13.33 per cent of the total moist weight and contained 14.81 per cent of the total nitrogen. Similar ratios hold for the distribution of phosphoric acid and ash. This indicates that the sprouts obtained the nitrogen, phosphoric acid, and ash in certain proportions from the tubers, the tubers simply acting as reservoirs for the sprouts. The action of the sprouts was selective, as might be expected in young, growing tissue. The solids of the sprouts contained 4 per cent of nitrogen, while the solids of the tubers and skins contained less than 2 per cent. In the Irish Cobbler the percentage of ash, phosphoric acid, and nitrogen remaining in the tubers after sprouting had ceased was less than 50 per cent of the total.

Buckner (3) found 17.77 per cent of the total phosphoric acid in the sprouts and 67.13 per cent in the exhausted tubers. Because he found that 50 per cent or more of the mineral matter was left in the tubers, he thought that a large amount of ash was necessary to bring about the katabolic changes involved in sprouting. He obtained the following results:

Material examined.	Ash in solids.	P_2O_5 in ash.	CaO in ash.	MgO in ash	K_2O in ash.	SiO_2 in ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
New sprouts	9.91	12.56	0.90	2.72	40.40	0.95
Skins	8.14	5.89	1.70	1.33	40.33	8.45
Tubers	4.37	12.4	.75	2.25	53.52	.60

Chlorin and other ash constituents in potato ash are not included in Buckner's analyses.

SUMMARY

Analytical data for sprouts, skins, and tubers of three varieties of Bordeaux-sprayed potatoes stored at labratory temperature (average 70° F.) showed little variation in composition for the different varieties, the age of the sprout apparently influencing the composition more than the variety. Data for Green Mountain sprouts, skins, and tubers from Bordeaux-sprayed and from unsprayed plants indicated that the spray did not change the rate of growth or the composition of the sprouts.

Biological changes are taking place in the formation and growth of the sprouts. The percentage distribution of the nitrogenous substances showed the sprouts to contain more protein and less diamino and other basic nitrogen than the skins and tubers. The sprouts showed a selective action in withdrawing from the tubers nitrogen, ash, phosphoric acid, and water in larger proportion than was originally present.

The sprouts remained fresh and continued to grow as long as any water was available in the tubers. The sprouts of the Irish Cobbler tubers constituted 17 per cent of the total weight of the sprouts and tubers at the time the tubers were exhausted, while the Green Mountain sprouts, under the same conditions, constituted 5.5 per cent of the total weight. An increased concentration or activity of the growth-promoting agent or agents in Irish Cobbler tubers is suggested.

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FURTHER STUDIES IN THE DETERIORATION OF SUGARS IN STORAGE[1]

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In a study of the deterioration of Cuban raw sugars stored under normal conditions during the summer of 1919 certain conclusions were indicated concerning the correlation between chemical and bacteriological analysis, with special reference to losses in sucrose content.[2] It was shown that the keeping quality of a sugar depends not only upon the moisture ratio but likewise upon the content of microorganisms and that any prediction concerning deterioration involves a concomitant consideration of these two factors.[3] In the present investigation of sugars stored in 1920 the technic and procedure were identical with those previously used, which have been described elsewhere;[4] the only difference was that in 1920 the position of the bags in any single pile was reversed after four weeks' incubation to obtain uniformity of environment, and the bags were placed on scantling 1 foot from the floor and were protected by a covering of a single layer of sacks.

It was especially designed to have under observation as large a variety of sugars as possible, and from the succeeding data it will be seen that all extremes in polarization, moisture, and number of microorganisms are to be found. This is not only true of the different marks chosen but more significantly of the bags of each mark. As a rule 3 bags which varied sufficiently to be considered representative of the mark were chosen, and in some instances, where the variations in a lot were unusual, 6 bags were taken. It may be mentioned parenthetically that it was planned to sample the bags monthly for six months, but because of the postponed arrival of sugar it was necessary to delay the initial sampling and thus curtail the number of analyses. In the succeeding tables the names of the marks have been abbreviated to symbols, since there has been no intention of subjecting any of the sugars to criticism. All the sugars came from Cuba with the exception of 2 marks, M and A, from Porto Rico. Seven of the 10 marks represent sugars transported by vessel, the remaining 3 (Am, O, and Phil) having come by railroad via

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Key West. The following numbers of bags of each mark were received: F, 2,303; Port, 4,694; Cun, 17,000; Agr, 13,500; Cab, 10,000; Am, 2,831; O, 1,406; Pil, 4,060; M, 11,300; Ag, 5,000—totaling 23,070,080 pounds of sugar. The bags under observation were chosen from among these.

In Table I are presented the chemical and bacteriological analyses of the sugars under normal storage. The moisture ratio or factor of safety has been calculated according to the formula M. R. $= \frac{\text{Moisture}}{100 - \text{polarization}}$, a detailed discussion of which may be found in previous publications.[1] The last column refers to the percentage of molds based on the total number of microorganisms per gram.

TABLE I.—*Chemical and bacteriological analyses of Cuban raw sugars in storage*[2]

TRANSPORTED BY VESSEL

Mark No.	Part of bag.	Date of sampling.	Polarization.	Loss in polarization.	Moisture.	Reducing sugar.	Gain in reducing sugar.	Ash.	Moisture ratio.	Deterioration predicted from moisture ratio.	Number of microorganisms per gram.	Deterioration predicted from number of microorganisms.	Molds.
					Per cent.	*Per cent.*	*Per cent.*	*Per cent.*					*Per cent.*
F 1	Middle	Mar. 18	93.2	.....	2.90	1.83	.....	0.30	0.43	+	35,000	+	1
		Apr. 15	92.5	0.7	2.80	1.99	0.16	.....	.37	+	1,050,000	+	*
		May 13	91.4	1.8	3.17	3.13	1.30	.....	.37	....	30,000	.....	*
	Surface	Mar. 18	94.2	.....	2.31	1.30	.....	.30	.40	+	8,000	+	11
		Apr. 15	92.7	1.5	2.34	2.10	.80	.....	.32	+	18,000	+	3
		May 13	94.8	.....	1.70	1.26	.....	.....	.33	....	38,000	.....	*
F 2	Middle	Mar. 18	98.2	.....	.80	.54	.....	.28	.44	+	9,000	+	2
		Apr. 15	97.5	.7	.96	.59	.05	.....	.38	+	170,000	+	*
		May 13	96.9	1.3	1.00	.77	.23	.....	.32	....	17,000	.....	2
	Surface	Mar. 18	97.9	.....	.75	.58	.....	.27	.36	+	2,000	+	10
		Apr. 15	98.4	.....	.46	.50	.....	.....	.29	−	7,600	+	0
		May 13	97.8	.1	.70	.46	.....	.....	.31	....	2,100	.....	0
F 3	Middle	Mar. 18	96.4	.....	1.70	.63	.....	.33	.47	+	134,000	+	0
		Apr. 15	95.8	.6	1.62	.96	.33	.....	.39	+	7,000,000	+	0
		May 13	95.8	.6	1.67	1.50	.87	.....	40	....	10,000	.....	*
	Surface	Mar. 18	97.0	.....	1.20	.66	.....	.36	.40	+	156,000	+	0
		Apr. 15	96.6	.4	1.27	.85	.19	.....	.37	+	5,500,000	+	0
		May 13	95.3	1.2	1.50	1.37	.71	.....	.36	....	30,000	.....	0
Port 1	Middle	Mar. 18	96.5	.....	1.08	1.06	.....	.39	.31	+	240	+	3
		Apr. 15	96.3	.2	1.00	1.05	.....	.....	.27	−	1,500	+	3
		May 13	95.9	.6	1.30	.93	.....	.....	.31	....	6,000	.....	1
	Surface	Mar. 18	96.5	.....	1.10	1.08	.....	.42	.31	+	300	+	0
		Apr. 15	96.5	0	1.02	.98	.....	.....	.29	−	800	+	0
		May 13	96.3	.2	1.10	1.04	.....	.....	.30	....	7,000	.....	0
Port 2	Middle	Mar. 18	96.0	.....	1.18	1.16	.....	.45	.30	+	6,000	+	0
		Apr. 15	95.9	.1	1.10	1.09	.....	.....	.27	−	98	−	2
		May 13	95.8	.2	1.28	.97	.....	.....	.30	....	2,250	.....	0
	Surface	Mar. 18	96.2	.....	1.16	1.30	.....	.42	.30	+	1,150	+	0
		Apr. 15	96.0	.2	1.10	1.21	.....	.....	.28	−	150	−	0
		May 13	95.8	.4	1.19	1.02	.....	.....	.30	....	8,000	.....	*
Port 3	Middle	Mar. 18	95.5	.....	1.42	1.17	.....	.51	.32	+	1,000	+	10
		Apr. 15	95.5	0	1.25	1.09	.....	.....	.28	−	2,100	+	0
		May 13	95.1	.4	1.42	1.04	.....	.....	.30	....	1,800	.....	1
	Surface	Mar. 18	95.4	.....	1.42	1.04	.....	.55	.31	+	3,100	+	0
		Apr. 15	95.5	.....	1.10	1.05	.01	.....	.24	−	22,000	+	0
		May 13	95.4	0	1.37	.98	.....	.....	.30	....	2,150	.....	0

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[2] * Indicates negligible amount of mold.

TABLE I.—*Chemical and bacteriological analyses of Cuban raw sugars in storage*—Con.

TRANSPORTED BY VESSEL—continued

Mark No.	Part of bag.	Date of sampling.	Polarization.	Loss in polarization.	Moisture.	Reducing sugar.	Gain in reducing sugar.	Ash.	Moisture ratio.	Deterioration predicted from moisture ratio.	Number of microorganisms per gram.	Deterioration predicted from number of microorganisms.	Molds.
					Per cent.	*Per cent.*	*Per cent.*	*Per cent.*					*Per cent.*
Cun 1..	Middle.	Mar. 22	94.4	.....	2.00	0.98	.....	1.02	0.36	+	200	+	0
		Apr. 19	95.4	.....	1.75	.76	.....	.....	.31	+	400	+	0
		May 17	95.8	.....	1.74	.47	.....	.....	.40	....	8,000	.....	0
	Surface.	Mar. 22	94.2	.....	1.94	1.10	.....	.....	.34	+	400	+	0
		Apr. 19	94.4	.....	2.10	.90	.....	.....	.46	+	85	−	0
		May 17	94.4	.....	2.15	.75	.....	.....	.38	....	1,100	.....	1
Cun 2..	Middle.	Mar. 22	94.5	.....	1.68	1.19	.....	.96	.30	+	1,700	+	0
		Apr. 19	94.1	.4	2.10	1.24	.05	.....	.36	+	110,000	+	0
		May 17	93.5	1.0	2.21	1.33	.14	.....	.34	....	120,000	.....	0
	Surface.	Mar. 22	94.4	.....	1.50	1.24	.....	.99	.27	−	1,350	+	0
		Apr. 19	94.5	.....	1.85	1.17	.....	.....	.34	+	2,500	+	0
		May 17	92.0	.....	2.00	1.91	.67	.....	.25	....	160,000	.....	0
Cun 3..	Middle.	Mar. 22	95.3	.....	1.27	.90	.....	.81	.27	−	575	+	77
		Apr. 19	95.3	0	1.52	.81	.....	.....	.32	+	190	−	17
		May 17	95.0	.....	1.70	.83	.....	.....	.24	....	5,000	.....	1
	Surface.	Mar. 22	95.8	.....	1.30	.87	.....	.80	.31	+	350	+	94
		Apr. 19	95.0	.8	1.74	.85	.....	.....	.35	+	190	−	71
		May 17	94.8	1.0	1.66	.77	.....	.....	.32	....	480	.....	7
Cun 4..	Middle.	Mar. 22	97.0	.....	1.32	.52	.....	.50	.44	+	14,000	+	0
		Apr. 19	95.3	1.7	1.80	1.35	.83	.....	.38	+	100,000	+	0
		May 17	93.8	3.2	2.08	2.14	1.62	.....	.33	....	19,000	.....	*
	Surface.	Mar. 22	97.5	.....	1.04	.50	.....	.48	.35	+	14,000	+	0
		Apr. 19	96.2	.8	1.51	.51	.01	.....	.40	+	20,000	+	0
		May 17	94.0	3.0	1.81	2.13	1.63	.....	.30	....	4,100	.....	0
Cun 5..	Middle.	Mar. 22	93.8	.....	2.21	1.01	.....	1.02	.36	+	600	+	25
		Apr. 19	94.0	.....	2.33	.92	.....	.....	.39	+	2,700	+	2
		May 17	94.5	.....	2.34	.52	.....	.....	.43	....	22,000	.....	*
	Surface.	Mar. 22	94.2	.....	2.10	1.01	.....	.98	.36	+	235	+	4
		Apr. 19	94.8	.....	1.83	.61	.....	.....	.35	+	336	+	4
		May 17	94.6	.....	1.89	.64	.....	.....	.35	....	1,000	.....	2
Cun 6..	Middle.	Mar. 22	96.2	.....	1.03	.99	.....	.72	.27	−	125	−	0
		Apr. 19	95.4	.8	1.53	1.01	.02	.....	.33	+	250	+	3
		May 17	94.9	1.3	1.70	1.08	.09	.....	.33	....	3,000	.....	3
	Surface.	Mar. 22	95.5	.....	1.20	1.22	.....	.78	.27	−	475	+	10
		Apr. 19	94.9	.6	1.80	1.16	.....	.....	.35	+	575	+	3
		May 17	95.2	.....	1.46	1.06	.....	.....	.30	....	500	.....	8
Agr 1..	Middle.	Mar. 30	96.6	.....	1.02	.89	.....	.48	.30	+	67	−	0
		Apr. 27	96.3	.3	1.20	.82	.....	.....	.33	+	1,000	+	25
		May 21	96.0	.6	1.30	.84	.....	.....	33	....	3,100	.....	3
	Surface.	Mar. 30	96.7	.....	1.00	.83	.....	.50	.30	+	125	−	0
		Apr. 27	96.3	.4	1.16	.88	.05	.....	.31	+	350	+	5
		May 21	96.2	.5	1.04	.80	.....	.....	.27	....	930	.....	0
Agr 2..	Middle.	Mar. 30	97.3	.....	.94	.57	.....	.48	.35		120,000		0
		Apr. 27	96.8	.5	1.16	.77	.20	.....	.36		115,000		0
		May 21	96.0	1.3	1.08	1.04	.47	.....	.27	....	145,000		*
	Surface.	Mar. 30	97.4	.....	.94	.58	.....	.48	.36		18,000		0
		Apr. 27	97.5	.....	.90	.45	.....	.....	.36		7,500		1
		May 21	97.3	.1	.90	.53	.08	.....	.30		215		0
Agr 3..	Middle.	Mar. 30	96.6	.....	1.02	.78	.....	.54	.30		190		0
		Apr. 27	96.4	.2	1.10	.76	.....	.....	.30		1,800		*
		May 21	96.3	.3	1.00	.77	.....	.....	.33		1,160		3
	Surface.	Mar. 30	96.5	....	1.07	1.00	.....	.59	.30		283		0
		Apr. 27	96.4	.1	1.09	.81	.....	.....	.30		300		10
		May 21	96.5	.....	1.14	.81	.....	.....	.33		220		28
Cab 1..	Middle.	Mar. 30	94.8	.....	1.30	1.45	.....	.57	.25		300		0
		Apr. 27	94.7	.1	1.50	1.48	.03	.....	.28		55,750		0
		May 21	95.0	.....	1.59	.80	.....	.....	.36		225,000		*
	Surface.	Mar. 30	94.2	.....	1.70	1.60	.....	.59	.29		250		0
		Apr. 27	94.4	.....	1.62	1.53	.....	.....	.29		2,200		*
		May 21	94.8	.....	1.60	1.04	.....	.....	.31		55,000		2
Cab 2..	Middle.	Mar. 30	94.8	.....	1.28	1.44	.....	.57	.25		290		0
		Apr. 27	94.8	.....	1.45	1.37	.....	.....	.27		165		0
		May 21	95.0	.....	1.54	1.35	.....	.....	.31		2,000		0
	Surface.	Mar. 30	94.7	.....	1.40	1.42	.....	.52	.26		210		0
		Apr. 27	94.6	.1	1.31	1.42	.....	.....	.24		500		*
		May 21	94.5	.2	1.43	1.42	.....	.....	.26		350		3

TABLE I.—*Chemical and bacteriological analyses of Cuban raw sugars in storage*—Con.

TRANSPORTED BY VESSEL—continued

Mark No.	Part of bag.	Date of sampling.	Polarization:	Loss in polarization.	Moisture.	Reducing sugar.	Gain in reducing sugar.	Ash.	Moisture ratio.	Deterioration predicted from moisture ratio.	Number of microorganisms per gram.	Deterioration predicted from number of microorganisms.	Molds.
					Per cent.	*Per cent.*	*Per cent.*	*Per cent.*					*Per cent.*
Cab 3..	Middle.	Mar. 30	95.2	.....	1.80	1.02	.....	0.61	0.38		110,000		0
		Apr. 27	95.1	.....	1.86	.80	.....	.....	.40		6,000,000		0
		May 21	95.8	.....	1.64	.76	.....	.....	.40		52,000		0
	Surface.	Mar 30	94.8	.....	1.74	1.35	.....	.69	.33		1,260		0
		Apr. 27	95.4	.....	1.30	.87	.....	.....	.28		110,000		1
		May 21	95.4	.....	1.33	.69	.....	.....	.29		8,000		0

TRANSPORTED BY RAILWAY

Am 1..	Middle.	Apr. 1	92.0	.....	4.00	1.14	.....	0.40	0.50		4,000		1
		Apr. 29	90.8	1.2	3.40	2.24	1.10	.....	.37		120,000		1
		May 24	89.5	2.5	3.21	3.44	2.30	.....	.31		33,000	*	
	Surface.	Apr. 1	96.0	.....	1.01	.81	.....	.48	.25		2,400		17
		Apr. 29	94.8	1.2	1.50	1.62	.81	.....	.30		4,900		0
		May 24	92.5	3.5	2.00	2.74	1.98	.....	.27		1,900		0
Am 2..	Middle.	Apr. 1	95.4	.....	1.60	1.47	.....	.36	.35		19,000		0
		Apr. 29	94.2	1.2	1.35	2.34	.87	.....	.23		90,000		0
		May 24	93.0	2.4	1.96	3.01	.....	.....	.28		20,000	*	
	Surface.	Apr. 1	96.8	.....	.94	.76	.....	.33	.30		850		3
		Apr. 29	97.0	.....	.90	.91	.15	.....	.30		14,000		0
		May 24	95.7	1.1	1.15	1.54	.78	.....	.27		1,230		13
Am 3..	Middle.	Apr. 1	95.5	....	1.92	.98	.....	.36	.43		30,000	*	
		May 29	95.0	.5	1.30	2.00	1.02	.....	.26		65,000		1
		May 24	94.5	1.0	1.41	2.29	1.31	.....	.26		2,100		3
	Surface.	Apr. 1	96.8	.....	.90	.77	.....	.33	.29		4,000		1
		Apr. 29	96.5	.3	1.00	1.12	.35	.....	.29		4,000	*	
		May 24	95.0	1.8	1.43	2.15	1.38	.....	.29		400		0
Am 4..	Middle.	Apr. 1	95.8	.....	1.76	.81	.....	.45	.42		50,000	*	
		Apr. 29	94.4	1.4	2.47	1.69	.88	.....	.26		3,000	*	
		May 24	93.5	2.3	2.80	2.19	2.38	.....	.28		750		0
	Surface.	Apr. 1	96.2	.....	1.12	.91	.05	.45	.30		1,500		2
		Apr. 29	96.2	.....	1.14	.96	.....	.....	.30		280		0
		May 24	95.8	.4	1.10	1.26	.35	.....	.26		540		8
Am 5..	Middle.	Apr. 1	96.8	....	1.32	.69	.....	.36	.41		7,000	*	
		Apr. 29	95.2	1.6	1.16	1.92	1.23	.....	.24		115,000	*	
		May 24	94.8	2.0	1.33	2.29	1.60	.....	.24		2,000		0
	Surface.	Apr. 1	97.2	.....	.90	.70	.....	.39	.32		340		26
		Apr. 29	96.5	.7	.94	.98	.28	.....	.27		40,000		1
		May 24	97.0	.....	.85	.78	.08	.....	.28		1,420		5
Am 6..	Middle.	Apr. 1	95.5	.....	2.00	1.04	.....	.39	.44		300,000	*	
		Apr. 29	95.7	.....	1.09	1.71	.67	.....	.25		120,000	*	
		May 24	94.3	1.2	2.32	2.26	1.22	.....	.23		16,000		0
	Surface.	Apr. 1	97.0	.....	1.24	.73	.....	.40	.41		300		8
		Apr. 29	97.2	.....	1.02	.84	.11	.....	.36		10,000		0
		May 24	97.4	.....	.80	.76	.....	.....	.31		450		0
O 1	Middle.	Apr. 5	96.6	.....	80	.66	.....	.54	.24	—	1,700	+	3
		May 3	96.3	.3	.76	.75	.09	.....	.21	—	435	+	0
		May 26	96.4	.2	.85	.75	.09	.....	.24	—	415	+	0
	Surface.	Apr. 5	96.9	.....	.59	.75	.....	.55	.19	—	335	+	1
		May 3	96.6	.3	.86	.76	.01	.....	.25	—	200	+	17
		May 26	96.9	.....	.76	.75	.....	.....	.21	—	350	+	15
O 2	Middle.	Apr. 5	96.9	.....	.68	.64	.....	.57	.22	—	550	*	10
		May 3	96.6	.3	.70	.62	.02	.....	.21	—	140	—	0
		May 26	96.8	.1	.60	.64	.....	.....	.19		2,100		0
	Surface.	Apr. 5	97.0	.....	.60	.70	.....	.57	.20	—	275	+	2
		May 3	96.2	.8	2.00	.68	.....	.....	.26	—	500	*	*
		May 26	96.5	.5	.82	.69	.....	.....	.27		4,500	*	*
O 3	Middle.	Apr. 5	96.3	.....	.95	.75	.....	.63	.26	—	700	+	
		May 3	95.9	.4	1.00	.77	.02	.....	.24	—	1,500	+	0
		May 26	96.1	.2	.93	.90	.15	.....	.24	—	1,100		0
	Surface.	Apr. 5	96.5	.....	.76	.75	.....	.63	.18	—	630	+	5
		May 3	95.9	.6	1.00	.85	.08	.....	.24	—	2,000	+	1
		May 26	96.2	.3	.90	.87	.12	.....	.24		1,300		0

TABLE I.—*Chemical and bacteriological analyses of Cuban raw sugars in storage*—Continued

TRANSPORTED BY RAILWAY—continued

Mark No.	Part of bag.	Date of sampling.	Polarization.	Loss in polarization.	Moisture.	Reducing sugar.	Gain in reducing sugar.	Ash.	Moisture ratio.	Deterioration predicted from moisture ratio.	Number of microorganisms per gram.	Deterioration predicted from number of microorganisms.	Molds.
					Per cent.	*Per cent.*	*Per cent.*	*Per cent.*					*Per cent.*
Pil 1	Middle.	Apr. 5	96.0	.....	1.36	0.52	.....	0.42	0.34	+	900	+	2
		May 3	95.9	.1	1.20	.60	.08	.....	.29	—	245,000	+	*
		May 26	96.6	.....	1.42	.45	.....	.....	.42		53,000		1
	Surface.	Apr. 5	95.7	.....	1.10	1.05	.....	.45	.26	—	340	+	4
		May 3	96.4	.....	1.02	.47	.....	.....	.28	—	240,000	+	*
		May 26	96.7	.....	.81	.55	.....	.....	.25		39,000		0
Pil 2	Middle.	Apr. 5	95.6	.....	1.70	.70	.....	.51	.39	+	4,250	+	0
		May 3	95.2	.4	1.53	.75	.05	.....	.32	+	80,000	+	0
		May 26	95.0	.6	1.20	1.26	.56	.....	.24		26,000		0
	Surface.	Apr 5	95.8	.....	1.30	1.10	.....	.54	.31	+	550	*	1
		May 3	95.9	.....	1.02	.49	.....	.....	.25	—	.....	.....	0
		May 26	95.8	.....	1.06	.92	.....	.....	.25		1,850	+	.....
Pil 2	Middle.	Apr. 5	94.4	.....	1.88	1.35	.....	.42	.34	+	210,000	+	* 0
		May 3	94.4	.....	1.60	1.36	.01	.....	.29	—	210,000	+	
		May 26	94.0	.4	1.54	1.74	.39	.....	.26		5,500		0
	Surface.	Apr. 5	96.5	.....	1.00	.94	.....	.40	.29	—	4,750	+	0
		May 3	95.4	1.1	1.70	.78	.....	.....	.37	+	26,000	+	*
		May 26	95.6	.9	1.35	1.32	.38	.....	.31		1,900		9

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M 1	Middle.	Apr. 5	96.0	.....	1.10	0.61	.....	0.70	0.28	—	120,000	+	0
		May 3	95.3	0.7	1.30	.77	0.16	.....	.28	—	75,000	+	*
		May 26	95.4	.6	1.17	1.20	.59	.....	.25		130,000		*
	Surface.	Apr. 5	96.5	.....	.70	.68	.....	.66	.20	—	2,300	+	4
		May 3	95.6	.9	1.29	.72	.04	.....	.29	—	Lost		0
		May 26	94.8	1.7	1.36	1.34	.62	.....	.26		360		5
M 2	Middle.	Apr. 5	96.2	.....	.86	1.05	.....	.48	.23	—	1,050	+	2
		May 3	95.9	.3	1.15	1.04	.....	.....	.28	—	70	—	0
		May 26	96.2	.....	1.02	1.04	.....	.....	.27		400		0
	Surface.	Apr. 5	97.0	.....	.62	.97	.....	.50	.27	—	260	+	0
		May 3	96.0	1.0	1.23	.97	.....	.....	.31	+	370	+	0
		May 26	96.4	.6	.85	.93	.....	.....	.23		225		0
M 3	Middle.	Apr. 5	96.3	.....	1.16	.48	.....	.66	.31	+	350	+	0
		May 3	95.8	.5	1.27	.83	.....	.....	.30	*	100,000	+	*
		May 26	95.2	1.1	1.33	1.53	1.05	.....	.28		200,000		*
	Surface.	Apr. 5	96.3	.....	.90	.75	.....	.65	.24	—	800,000	+	* 0
		May 3	96.0	.3	1.05	.83	.08	.....	.26	—	550	+	
		May 26	96.2	.1	1.03	.83	.08	.....	.27		27,000		0
Ag 1	Middle.	Apr. 5	96.0	.....	1.00	1.04	.....	.63	.25	—	175	—	0
		May 3	95.5	.5	1.16	1.08	.04	.....	.26	—	250	+	0
		May 26	95.8	.2	1.04	.90	.....	.....	.21		650		8
	Surface.	Apr. 5	96.3	.....	.92	1.16	.....	.60	.25	—	310	+	0
		May 3	95.6	.7	1.26	1.01	.....	.....	.29	—	2,600	+	*
		May 26	95.9	.4	1.29	1.06	.....	.....	.31		540		0
Ag 2	Middle.	Apr. 5	96.6	.....	.75	.85	.....	.54	.22	—	325	+	0
		May 3	95.6	1.0	1.20	.98	.13	.....	.27	—	4,000	+	0
		May 26	96.0	.6	1.03	.95	.10	.....	.26		4,500		*
	Surface.	Apr. 5	96.8	.....	.70	.93	.....	.54	.22	—	200	+	30
		May 3	96.3	.5	1.08	.87	.....	.....	.29	—	4,500	+	2
		May 26	96.5	.3	.88	.90	.....	.....	.25		150		0
Ag 3	Middle.	Apr. 5	94.4	.....	1.35	1.28	.....	.80	.24	—	117	—	9
		May 3	94.2	.2	1.38	1.50	.22	.....	.24		200	+	5
		May 26	94.2	.2	1.56	1.47	.19	.....	.27		2,750		1
	Surface.	Apr. 5	94.8	.....	1.16	1.41	.....	.78	.22	—	230	+	33
		May 3	93.8	1.0	1.63	1.42	.01	.....	.31	+	450	+	0
		May 26	94.2	.6	1.43	1.39	.....	.....	.25		1,100		1

From the data given in Table I it will be seen that the sugars vary in initial polarization from 92 to 98.2; in moisture from 0.75 to 2.90; in percentage of reducing sugars from 0.52 to 1.83; in percentage of ash from

0.28 to 1.02; in moisture ratio from 0.18 to 0.50; in number of microorganisms per gram from 67 to 134,000; and in percentage of molds from 0 to 94. It is apparent that certain generalizations may be drawn from Table I—namely, that there is a reduction in polarization in practically all sugars during storage, a fact already established. Furthermore, it is apparent that a decrease in polarization is generally accompanied by an increase in reducing sugars. As might be anticipated, when deterioration sets in during the first four weeks of incubation, it continues through the second four weeks, although it would be difficult to state whether the deterioration is more active in the second period of four weeks than the first. While it is not to be expected that the number of microorganisms present can be correlated with polarization, nevertheless, in general, the greatest number of microorganisms occurs where the moisture ratio is highest, and as a corollary we have observed that the lighter colored sugars having the higher moisture ratios deteriorate most rapidly.

The temperature and relative humidity in New Orleans during the months of storage of these sugars are given in Table II. It may be said that in 1920 these were somewhat lower than the average. Table III graphically represents the differences between successive samplings together with a comparison between the last sampling and the first. There is a fairly close agreement to be found between the results for bags of one mark; therefore these bags have been summarized in Table IV.

TABLE II.—*Temperature and relative humidity at New Orleans, La., during March, April, and May, 1920*

Month.	Relative humidity.	Temperature.		
		Maximum.	Minimum.	Mean.
		°F.	°F.	°F.
March	88	84	27	59.40
April	80	87	39	65.85
May	75	92	57	75.75
Average	81	88	41	67.00

TABLE III.—*Differences between successive samplings of sugars in normal storage*[1]

Mark No.	Part of bag.	Date of sampling.	Polarization.	Moisture.	Reducing sugar.	Moisture ratio.	Number of microorganisms per gram.	Molds.
				Per cent.	*Per cent.*			
F 1	Middle	Apr. 15	−	−	+	−	+	−
		May. 13	−	+	+	*	−	*
		Mar. 18	−	+	+	−	−	−
	Surface	Apr. 15	−	+	+	−	+	−
		May 13	+	−	−	+	+	−
		[2]Mar. 18	+	−	−	−	+	−

[1] * signifies no change; + signifies increase; − signifies decrease.
[2] Third sampling compared with first.

TABLE III.—*Differences between successive samplings of sugars in normal storage*—Continued

Mark No.	Part of bag.	Date of sampling.	Polarization.	Moisture.	Reducing sugar.	Moisture ratio.	Number of microorganisms per gram.	Molds.
				Per cent.	*Per cent.*			
F 2	Middle	Apr. 15	−	+	+	−	+	−
		May 13	−	+	+	−	−	+
		[2]Mar. 18	−	+	+	−	+	*
	Surface	Apr. 15	+	−	−	−	+	−
		May 13	−	+	−	+	−	*
		[2]Mar. 18	−	−	−	−	+	*
F 3	Middle	Apr. 15	−	−	+	−	+	*
		May 13	*	+	+	+	−	+
		[2]Mar. 18	−	−	+	−	−	+
	Surface	Apr. 15	−	+	+	−	+	*
		May 13	−	+	+	−	−	*
		[2]Mar. 18	−	+	+	−	−	*
Port 1	Middle	Apr. 15	−	−	−	−	+	*
		May 13	−	+	−	+	+	−
		[2]Mar. 18	−	+	−	*	+	−
	Surface	Apr. 15	*	−	−	−	+	*
		May 13	−	+	+	+	+	*
		[2]Mar. 18	−	*	−	−	+	*
Port 2	Middle	Apr. 15	−	−	−	−	−	+
		May 13	−	+	−	+	+	−
		[2]Mar. 18	−	+	−	*	−	*
	Surface	Apr. 15	−	−	−	−	−	*
		May 13	−	+	−	+	+	+
		[2]Mar. 18	−	+	−	*	+	+
Port 3	Middle	Apr. 15	*	−	−	−	+	−
		May 13	−	+	−	+	−	+
		[2]Mar. 18	−	*	−	−	+	−
	Surface	Apr. 15	+	−	+	−	+	*
		May 13	−	+	−	−	−	*
		[2]Mar. 18	*	−	−	−	−	*
Cun 1	Middle	Apr. 19	+	−	−	−	*	*
		May 17	+	−	−	+	+	*
		[2]Mar. 22	+	−	−	+	+	*
	Surface	Apr. 19	+	+	−	+	−	*
		May 17	*	+	−	−	+	*
		[2]Mar. 22	+	+	−	+	+	*
Cun 2	Middle	Apr. 19	−	+	+	+	+	−
		May 17	−	+	+	−	+	*
		[2]Mar. 22	−	+	+	+	+	*
	Surface	Apr. 19	+	+	−	+	+	*
		May 17	−	+	+	−	+	*
		[2]Mar. 22	−	+	+	−	−	−
Cun 3	Middle	Apr. 19	*	+	−	+	−	−
		May 17	−	+	+	+	+	−
		[2] Mar. 22	−	+	−	−	−	−
	Surface	Apr. 19	−	+	−	+	+	−
		May 17	−	−	−	−	+	−
		[2] Mar. 22	−	+	−	+	−	*
Cun 4	Middle	Apr. 19	−	+	+	−	+	*
		May 17	−	+	+	−	+	+
		[2] Mar. 22	−	+	+	−	+	*
	Surface	Apr. 19	−	+	+	+	−	*
		May 17	−	+	+	−	−	*
		[2] Mar. 22	−	+	+	−	−	*

[2] Third sampling compared with first.

TABLE III.—*Differences between successive samplings of sugars in normal storage*—Continued

Mark No.	Part of bag.	Date of sampling.	Polarization.	Moisture.	Reducing sugar.	Moisture ratio.	Number of microorganisms per gram.	Molds.
				Per cent.	*Per cent.*			
Cun 5....	Middle.	Apr. 19	+	+	−	+	+	−
		May 17	+	+	−	+	+	−
		[2] Mar. 22	+	+	−	+	+	−
	Surface.	Apr. 19	+	−	−	−	+	−
		May 17	−	+	+	*	+	*
		[2] Mar. 22	+	−	−	−	+	−
Cun 6....	Middle.	Apr. 19	−	+	+	+	+	−
		May 17	−	+	+	*	+	+
		[2] Mar. 22	−	+	+	+	+	*
	Surface.	Apr. 19	−	+	−	+	+	+
		May 17	+	−	−	−	−	−
		[2] Mar. 22	−	+	−	+	−	+
Agr 1....	Middle.	Apr. 27	−	+	−	+	+	−
		May 21	−	+	+	*	+	+
		[2] Mar. 30	−	+	−	+	+	−
	Surface.	Apr. 27	−	+	+	+	+	+
		May 21	−	−	−	−	+	+
		[2] Mar. 30	−	+	−	−	+	*
Agr 2....	Middle.	Apr. 27	−	+	+	+	−	*
		May 21	−	−	+	−	+	+
		[2] Mar. 30	−	+	+	−	+	+
	Surface.	Apr. 27	+	−	−	*	−	+
		May 21	−	*	+	−	−	−
		[2] Mar. 30	−	−	−	−	−	*
Agr 3....	Middle.	Apr. 27	−	+	−	*	+	+
		May 21	−	−	+	+	−	+
		[2] Mar. 30	−	−	−	+	+	+
	Surface.	Apr. 27	−	+	−	*	+	+
		May 21	+	+	*	+	−	+
		[2] Mar. 30	*	+	−	+	−	+
Cab 1....	Middle.	Apr. 27	−	+	+	+	+	*
		May 21	+	+	−	+	+	+
		[2] Mar. 30	+	+	−	+	+	+
	Surface.	Apr. 27	+	−	−	*	+	+
		May 21	+	−	−	+	+	−
		[2] Mar. 30	+	−	−	+	+	−
Cab 2....	Middle.	Apr. 27	*	+	−	+	−	*
		May 21	+	+	−	+	+	*
		[2] Mar. 30	+	+	−	+	+	*
	Surface.	Apr. 27	−	−	*	−	+	+
		May 21	−	+	*	+	−	+
		[2] Mar. 30	−	+	*	*	+	+
Cab 3....	Middle.	Apr. 27	+	+	−	+	*	*
		May 21	+	−	−	*	−	*
		[2] Mar. 30	+	−	−	+	−	*
	Surface.	Apr. 27	+	−	−	+	+	−
		May 21	*	+	−	+	−	*
		[2] Mar. 30	+	−	−	−	+	−
Am 1....	Middle.	Apr. 29	−	−	+	−	+	*
		May 24	−	−	+	−	−	−
		[2] Apr. 1	−	−	+	−	+	−
	Surface.	Apr. 29	−	+	+	+	+	*
		May 24	−	+	+	−	−	−
		[2] Apr. 1	−	+	+	+	−	−

[1] Third sampling compared with first.

TABLE III.—*Differences between successive samplings of sugars in normal storage*—Continued

Mark No.	Part of bag.	Date of sampling.	Polarization.	Moisture.	Reducing sugar.	Moisture ratio.	Number of microorganisms per gram.	Molds.
				Per cent.	*Per cent.*			
	Middle	Apr. 29	−	−	+	−	+	*
		May 24	−	+	+	+	−	+
		[2] Apr. 1	−	+	+	−	+	+
Am 2	Surface	May 29	+	−	+	*	+	−
		May 24	−	+	+	−	−	+
		[2] Apr. 1	−	+	+	−	+	+
	Middle	Apr. 29	−	−	+	−	+	+
		May 24	−	+	+	*	−	+
		[2] Apr. 1	−	−	+	−	−	+
Am 3	Surface	Apr. 29	−	+	+	*	*	−
		May 24	−	+	+	*	−	−
		[2] Apr. 1	−	+	+	*	−	−
	Middle	Apr. 29	−	−	+	−	−	*
		May 24	−	+	+	+	−	−
		[2] Apr. 1	−	+	+	−	−	−
Am 4	Surface	Apr. 29	*	+	+	*	−	−
		May 24	−	−	+	−	+	+
		[2] Apr. 1	−	−	+	−	−	+
	Middle	Apr. 29	−	−	+	−	+	*
		May 24	−	+	+	*	−	−
		[2] Apr. 1	−	+	+	−	−	−
Am 5	Surface	Apr. 29	−	+	+	−	+	−
		May 24	+	−	−	+	−	+
		[2] Apr. 1	−	−	+	−	+	−
	Middle	Apr. 29	+	−	+	−	−	*
		May 24	−	+	+	−	−	−
		[2] Apr. 1	−	−	+	−	−	−
Am 6	Surface	Apr. 29	+	−	+	−	+	−
		May 24	+	−	−	−	−	*
		[2] Apr. 1	+	−	+	−	+	−
	Middle	May 3	−	−	+	−	−	*
		May 26	+	+	*	+	−	−
		[2] Apr. 5	−	−	+	*	−	−
O 1	Surface	May 3	−	+	+	+	+	+
		May 26	+	−	−	−	+	+
		[2] Apr. 5	*	+	*	+	+	−
	Middle	May 3	−	+	−	−	−	*
		May 26	+	−	+	−	+	*
		[2] Apr. 5	−	−	*	−	+	−
O 2	Surface	May 3	−	+	−	+	+	*
		May 26	+	−	+	+	+	−
		[2] Apr. 5	−	+	−	+	+	−
	Middle	May 3	−	+	+	−	+	*
		May 26	+	−	−	*	−	−
		[2] Apr. 5	−	−	+	−	+	−
O 3	Surface	May 3	−	+	+	+	+	−
		May 26	+	−	+	*	−	−
		[1] Apr. 5	−	+	+	+	+	−
	Middle	May 3	−	−	+	−	+	+
		May 26	+	+	−	+	−	−
		[2] Apr. 5	+	+	−	+	+	−
Pil 1	Surface	May 3	+	−	−	−	+	−
		May 26	+	−	+	−	+	−
		[2] Apr. 5	+	−	−	−	+	−

[1] Third sampling compared with first.

TABLE III.—*Differences between successive samplings of sugars in normal storage*—Continued

Mark No.	Part of bag.	Date of sampling.	Polarization.	Moisture.	Reducing sugar.	Moisture ratio.	Number of microorganisms per gram.	Molds.
				Per cent.	*Per cent.*			
Pil 2	Middle	May 3	−	−	+	−	+	*
		May 26	−	−	+	−	−	*
		[2] Apr. 5	−	−	+	−	+	*
	Surface	May 3	+	−	−	−		
		May 26	−	+	*			
		[2] Apr. 5	*	−	−			
Pil 3	Middle	May 3	*	−	+	−	*	+
		May 26	−	−	+	−	−	−
		[2] Apr. 5	−	−	+	−	−	*
	Surface	May 3	−	+	−	+	+	+
		May 26	+	−	+	−	−	+
		[2] Apr. 5	+	+	−	+	−	+
M 1	Middle	May 3	−	+	+	*	−	+
		May 26	+	−	+	−	+	*
		[2] Apr. 5	−	+	+	−	+	+
	Surface	May 3	−	+	+	+		
		May 26	−	+	+	−		
		[2] Apr. 5	−	+	+	+		
M 2	Middle	May 3	−	+	−	+	−	−
		May 26	+	−	*	−	+	*
		[2] Apr. 5	*	+	−	+	−	−
	Surface	May 3	−	+	*	+	+	*
		May 26	+	−	−	−	−	*
		[2] Apr. 5	−	+	−	−	−	*
M 3	Middle	May 3	−	+	+	−	+	+
		May 26	−	+	+	−	+	*
		[2] Apr. 5	−	+	+	−	+	+
	Surface	May 3	−	+	+	+	−	+
		May 26	+	−	*	+	+	−
		[2] Apr. 5	−	+	+	+	−	*
Ag 1	Middle	May 3	−	+	+	+	+	*
		May 26	+	−	−	−	+	+
		[2] Apr. 5	−	+	−	−	+	+
	Surface	May 3	−	+	−	+	+	+
		May 26	+	+	+	+	+	−
		[2] Apr. 5	−	+	−	+	+	*
Ag 2	Middle	May 3	−	+	+	+	+	*
		May 26	+	−	−	−	+	+
		[2] Apr. 5	−	+	+	+	+	+
	Surface	May 3	−	+	−	+	+	−
		May 26	+	−	+	−	−	−
		[2] Apr. 5	−	+	−	+	−	−
Ag 3	Middle	May 3	−	+	+	*	+	−
		May 26	*	+	+	+	+	−
		[2] Apr. 5	−	+	+	+	+	−
	Surface	May 3	−	+	+	+	+	−
		May 26	+	−	−	−	+	+
		[2] Apr. 5	−	+	−	+	+	−

[2] Third sampling compared with first.

TABLE IV.—*Summary of differences between successive samplings (average of bags of same mark)*[1]

Mark No.	Part of bag.	Date of sampling.	Polarization.	Moisture.	Reducing sugar.	Moisture ratio.	Number of microorganisms per gram.	Molds.
				Per cent.	*Per cent.*			*Per cent.*
F 1 to 3	Middle	Apr. 15	−	−	+	−	+	−
		May 13	−	+	+	*	−	+
		[2]Mar. 18	−	+	+	−	−	*
	Surface	Apr. 15	−	+	+	−	+	−
		May 13	−	+	−	+	−	*
		[2]Mar. 18	−	−	+	−	+	*
Port 1 to 3	Middle	Apr. 15	−	−	−	−	+	*
		May 13	−	+	−	+	+	−
		[2]Mar. 18	−	+	−	+	+	−
	Surface	Apr. 15	*	−	−	−	+	*
		May 13	−	+	−	+	+	*
		[2]Mar. 18	−	*	−	−	+	*
Cun 1 to 6	Middle	Apr. 9	−	+	*	+	+	−
		May 17	−	+	+	+	+	−
		[2]Mar. 22	−	+	*	+	+	*
	Surface	Apr. 9	*	+	−	+	+	−
		May 17	−	+	*	−	+	*
		[2]Mar. 22	−	+	−	*	+	−
Agr 1 to 3	Middle	Apr. 27	−	+	−	+	+	+
		May 21	−	−	+	*	+	+
		[2]Mar. 30	−	+	−	+	+	+
	Surface	Apr. 9	−	+	*	−	−	−
		May 17	−	*	−	−	−	*
		[2]Mar. 22	−	+	−	−	−	*
Cab 1 to 3	Middle	Apr. 27	*	+	−	+	+	+
		May 21	+	+	−	+	+	*
		[2]Mar. 30	+	+	−	*	+	*
	Surface	Apr. 27	+	−	−	+	−	*
		May 21	*	+	−	*	+	−
		[2]Mar. 30	+	−	−	−	+	*
Am 1 to 6	Middle	Apr. 29	−	−	+	*	−	−
		May 24	−	+	+	−	+	−
		[2]Apr. 1	−	*	+	−	−	−
	Surface	Apr. 29	−	+	+	−	+	+
		May 24	−	*	+	−	*	−
		[2]Apr. 1	−	*	+	−	−	−
O 1 to 3	Middle	May 3	−	+	*	*	−	*
		May 26	+	−	+	−	+	−
		[2]Apr. 5	−	−	+	+	+	*
	Surface	May 3	−	+	+	*	+	−
		May 26	+	−	+	+	+	−
		[2]Apr. 5	−	+	*	+	+	*
Pil 1 to 3	Middle	May 3	−	−	+	−	−	*
		May 26	−	−	+	*	+	*
		[2]Apr. 5	−	−	+	−	+	−
	Surface	May 3	+	−	−	−	+	−
		May 26	+	−	+	*	*	−
		[2]Apr. 5	*	−	−	+	*	−
M 1 to 3	Middle	May 3	−	+	+	*	−	+
		May 26	+	−	+	−	+	*
		[2]Apr. 5	−	+	+	−	+	+
	Surface	May 3	−	+	+	−	*	−
		May 26	+	−	+	−	−	*
		[2]Apr. 5	−	+	+	+	−	−

[1] *signifies no change; +signifies increase, −signifies decrease.
[2] Third sampling compared with first.

TABLE IV.—*Summary of differences between successive samplings (average of bags of same mark)*—Continued

Mark No.	Part of bag.	Date of sampling.	Polarization.	Moisture.	Reducing sugar.	Moisture ratio.	Number of microorganisms per gram.	Molds.
				Per cent.	*Per cent.*			*Per cent.*
Ag 1 to 3.	Middle.	May 3	−	+	+	+	+	*
		May 26	+	−	−	−	+	+
		[2]Apr. 5	−	+	+	+	+	−
	Surface.	May 3	−	+	−	+	+	−
		May 26	+	−	+	−	+	−
		[2]Apr. 5	−	+	−	+	+	−

[2] Third sampling compared with first.

It will be seen that in practically all instances there has been a reduction in polarization between successive samplings. With regard to moisture content, however, there appears to be an increase in a majority of instances. It is interesting in this connection to note that, with the exception of the Cab sugars, an increase in polarization is accompanied by a decrease in moisture content. Naturally, this means that there has actually been a loss in weight of sugar. Furthermore, it will be seen that the surface of each bag decreased in moisture content, or dried out, as might be expected, much more rapidly than the middle of the same bag. In the sugars which have deteriorated it will be observed that there has been an increase in percentage of reducing sugars in successive samplings. However, as a rule this increase is more noticeable in the middle of the bag than at the surface where the deterioration does continue to progress at the initial rate. The conditions of temperature and humidity were such as to preclude the possibility of deterioration taking place more rapidly from the surface of the bag than from the interior of the bag, as occurs under average conditions which were noted in the previous experiment.[1] The moisture ratio was variable and does not permit of any generalization.

In considering the number of microorganisms it will be seen that in most instances there was an increase between successive samplings. In general it was found in corroboration of the results previously set forth that the increase in numbers of microorganisms was relatively more rapid during the first month of incubation than subsequently. Likewise it is to be noted that there is usually a greater number of microorganisms in the middle of the bag than at the surface, where drying out occurs. It will be shown in Table V, which is again corroborative of previous work, that there is correlation between the number of microorganisms and deterioration where the initial content is high or multiplication has been rapid. The percentage of molds is variable, and a tendency to decrease

[1] KOPELOFF, Nicholas, and PERKINS, H. Z. E. *op. cit.*, 1920.

in the surface is to be noted during the first four weeks of incubation. It is evident, therefore, that these results agree very closely with those previously obtained, and this is of added significance when it is remembered that the range in variety of sugars is considerably greater.

TABLE V.—*Summary showing correlation between deterioration and number of microorganisms*

Mark No.	Part of bag.	Date of sampling.	Loss in polarization.	Gain in reducing sugar.	Number of microorganisms per gram.
				Per cent.	
Am 1	Middle	Third	2.5	2.30	120,000
	Surface	do	3.5	1.93	4,900
Cun 4	do	do	3.0	1.63	20,000
	Middle	do	3.2	1.58	100,000
Am 5	do	do	2.0	1.60	115,000
Am 4	do	do	2.3	1.38	50,000
Am 3	Surface	do	1.8	1.38	4,000
Am 3	Middle	do	1.0	1.31	65,000
F 1	do	do	1.8	1.30	1,650,000
Am 5	do	Second	1.6	1.23	70,000
Am 6	do	Third	1.2	1.22	120,000
Am 1	do	Second	1.2	1.10	4,000
M 3	do	Third	1.1	1.05	100,000
Am 3	do	Second	.5	1.02	30,000

Table V consists of a summary arranged in such a manner as to bring out clearly the correlation between the number of microorganisms and deterioration. The order of bags is based upon the increase in reducing sugars, since that represents the best criterion for determining deterioration. In addition, it will be noted that the loss in polarization is proportional to the gain in reducing sugars. Still more significant, however, is the fact that deterioration occurs in the presence of the maximum numbers of microorganisms. It may be mentioned that the number of microorganisms set down opposite any figure for gain in reducing sugars is the number occurring at the previous sampling, since that number was responsible for the deterioration found at the time of analysis. With three exceptions the greatest deterioration is to be found when there are more than 20,000 microorganisms per gram, and the average deterioration (represented by an increase of more than 1 per cent of reducing sugars) is to be found where there are 174,000 per gram. It is interesting to compare Table V with Table VI, which is a summary showing the maximum numbers of microorganisms where no deterioration has occurred. It will be seen at a glance that in only five instances has this number exceeded 8,000 per gram, the average being about 11,000 (unduly weighted because of the Cab sugar which was especially heavily infected). Thus, a comparison between Tables V and VI reveals quite clearly that large numbers of microorganisms are causally related to deterioration and that the converse is likewise true.

TABLE VI.—*Summary showing maximum numbers of microorganisms where no deterioration occurs*

Mark No.	Part of bag.	Number of microorganisms per gram.	Mark No.	Part of bag.	Number of microorganisms per gram.
P 1	Middle	6,000	Agr 1	Middle	3,100
	Surface	7,000	Agr 3	Middle	1,800
P 2	Middle	6,000		Surface	300
	Surface	8,000	Cab 2	Middle	2,000
P 3	Middle	2,100		Surface	500
	Surface	22,000	Cab 3	do	110,000
C 1	Middle	8,000	M 3	Middle	1,050
	Surface	1,100		Surface	370
C 3	Middle	5,000	Ag 1	do	2,600
	Surface	14,000	Ag 2	do	4,500
C 6	Middle	22,000	Pil 1	do	24,500
	Surface	1,000			

In Table VII the sugars analyzed have been ranked according to deterioration as based upon the greatest loss of polarization during normal storage. In compiling these data the analyses for all the bags of each mark were averaged. It is evident that the deterioration in the first six sugars mentioned was appreciable, the Am sugar being considerably more deteriorated than any others. Inasmuch as this sugar came by railroad as did the O and Pil sugars, it would be difficult to regard the means of transportation as the sole limiting factor. Since the former had a higher moisture ratio and considerably more microorganisms per gram, it is natural to suppose that it would deteriorate more rapidly under any environmental conditions.

TABLE VII.—*Sugars ranked according to greatest loss in polarization during normal storage*

Rank	Mark.	Part of bag.	Average loss in polarization per bag.	Rank.	Mark.	Part of bag.	Average loss in polarization per bag.
1	Am	Middle	1.5	1	Am	Surface	0.8
2	F	do	.9	2	M	do	.8
3	Cun	do	.7	3	Cun	do	.7
4	Agr	do	.6	4	Ag	do	.6
5	M	do	.5	5	F	do	.5
6	Ag	do	.4	6	O	do	.4
7	Pil	do	.3	7	Pil	do	.3
8	O	do	.2	8	Agr	do	.2
9	Port	do	.2	9	Port	do	.1
10	Cab	do	0	10	Cab	do	0

It is interesting to note further in Table VII that in the majority of cases the rank of sugars with regard to deterioration is the same for the middle of the bag and for the surface. For example, the Am sugar shows greatest deterioration both in the middle and at the surface, while the Port and Cab sugars show least in both cases.

It has been shown that it is possible to predict the keeping quality of a sugar (from the standpoint of mold infection) by the simultaneous consideration of moisture ratio and number of organisms per gram.[1] Evidence for a prediction based on the number of bacteria was likewise advanced.[1] In Table I the plus and minus signs in the columns labeled "Deterioration predicted from moisture ratio" and "Deterioration predicted from number of microorganisms per gram" represent the prediction of deterioration based upon these factors considered independently. In this case we have taken the critical moisture ratio and the number of bacteria per gram which are required to produce deterioration in four weeks at this temperature and humidity of incubation as 30 and 200, respectively. (Table VIII.) Where these conditions were higher, as in the experiment of 1919,[2] less than half this number of microorganisms will produce similar effects. If attention is focused upon the moisture ratio it will be seen that the factor of safety as worked out by previous investigators holds true to a limited extent. In other words, where the moisture ratio is above 0.30 to 0.33 deterioration usually sets in, while sugars with lower moisture ratios usually resist deterioration. However, there are any number of instances where this factor of safety fails to function as an adequate criterion, and we may turn with some confidence to the number of microorganisms per gram as a true index of deterioration. In fact, a careful analysis of the data presented in Table I shows that as a criterion for predicting deterioration the moisture ratio or factor of safety proved to be in agreement with the analyses in 57 instances and failed in 86 instances; in other words, it was only 40 per cent effective. On the other hand, the use of the number of microorganisms per gram as an index of deterioration resulted in 96 successful predictions and 47 failures, or an efficiency of 67 per cent, which is 27 per cent better than the factor of safety. In the 65 cases where the moisture ratio is in agreement with number of microorganisms for the theoretical prediction of deterioration, there was practical confirmation in the majority of instances.

[1] KOPELOFF, Nicholas, and KOPELOFF, Lillian. OP. CIT., 1920.
[2] KOPELOFF, Nicholas, and PERKINS, H. Z. E. OP. CIT., 1920.

TABLE VIII.—*Correlation of moisture ratio with number of microorganisms*[1]

MOISTURE RATIO

	0.18 to 0.21.	0.22.	0.23.	0.24.	0.25.	0.26.	0.27.	0.28.	0.29.	0.30.	0.31.	0.32.	0.33.	0.34.	0.35.	0.36.	0.37.	0.38.	0.39.	0.40.	0.41.	0.42+.
0 to 100	*	+		*	*	*	*	+		*	+											
100 to 200	* +				*	—	*	+		*	+											
200 to 300	*	+			*	—	+			—	*											
300 to 400	*		*			+	*															
400 to 500	+			*		+	*															
500 to 1,000																						
1,000 to 5,000																						
5,000 to 10,000																						
10,000 to 25,000																						
25,000 to 50,000																						
50,000 to 100,000																						
100,000 to 250,000																						
250,000 to 500,000																						
500,000 to 1,000,000																						
1,000,000 to 5,000,000																						
5,000,000+																						

[1] + signifies deterioration; — signifies no deterioration; * signifies doubtful deterioration.

It will be seen from Table VIII, where there has been graphically illustrated the correlation between moisture ratio and number of microorganisms per gram that while such a relationship is of necessity dependent upon the environmental conditions at hand and it is hazardous in consequence to derive any didactic conclusions, nevertheless certain generalizations appear significant. For example, with more than 50,000 microorganisms per gram in practically all instances there was deterioration at every moitsure ratio employed. As the number of microorganisms is increased beyond this point it is almost certain that deterioration will occur at any moisture ratio generally occurring in Cuban raw sugar. As the number of organisms per gram is decreased to about 500 we have evidence of less deterioration at moisture ratios below 0.36. However, where the moisure ratio remains above 0.36 deterioration is effected by more than this number. On the other hand, even where the moistuie ratio is reduced below 0.30, which is considered the critical point, there is ample evidence to indicate that deterioration may be induced by more than 200 microorganisms per gram. This corroborates the conclusions arrived at in the investigations previously referred to [1] and emphasizes again the necessity for reducing the mass infection in sugar. Thus, on the basis of polarization, moisture content, and bacteriological analysis, it is possible to predict the keeping quality of sugar and thereby introduce considerable economy by immediately disposing of those sugars which will deteriorate rapidly and storing only those proved to be capable of storage without serious loss. As a matter of actual manufacture, it should not be difficult to control the microorganisms to such an extent

[1] KOPELOFF, Nicholas, and PERKINS, H. Z. E., op. cit.
—— and KOPELOFF, LILLIAN, op. cit., 1919.
—— —— op. cit., 1920.

as to inhibit their detrimental activities. In this connection it may be stated that recent experiments have enabled us to develop a method for eliminating the microorganisms in sugar by the use of superheated steam in the centrifugal which destroys over 90 per cent of the microorganisms.[1]

It is, therefore, evident that sugar deterioration depends upon the two factors of moisture ratio and number of microorganisms per gram. Furthermore, if the number of microorganisms is sufficiently reduced, and if the moisture ratio is properly controlled, sugar deterioration may be satisfactorily prevented.

SUMMARY

(1) From the results presented a correlation has been established between deterioration and the number of microorganisms and between deterioration and the moisture ratio. This makes it possible, as previously stated,[2] to predict the keeping quality of sugar by a preliminary bacteriological and chem ical analysis.

(2) From 3 to 6 bags of Cuban raw sugars, each of 10 different marks, with moisture ratios varying from 0.18 to 0.50, were stored under normal conditions in a large warehouse and were analyzed chemically and bacteriologically at the beginning and after four and eight weeks, respectively. There was a loss in polarization in most of the sugars at the end of each period, which was generally accompanied by a gain in reducing sugars and moisture content.

(3) There was a decided increase in the number of microorganisms per gram, especially during the first four weeks, which could be correlated, within certain limitations, with deterioration. In general, there were more microorganisms in the middle of the bag than at the surface. A large initial infection or rapid multiplication of microorganisms was responsible for an increase in deterioration.

(4) It has been shown that the use of superheated steam in the centrifugal will reduce the number of microorganisms more than 90 per cent and consequently may eliminate deterioration if the moisture ratio is likewise properly controlled.

[1] KOPELOFF, Nicholas. THE PREVENTION OF SUGAR DETERIORATION BY THE USE OF SUPERHEATED STEAM IN CENTRIFUGALS. *In* Jour. Indus. and Engin. Chem., v. 12, no. 9, p. 862–862, 1 fig. 1920.

[2] —— KOPELOFF, Lillian. OP. CIT., 1920.

FREEZING OF FRUIT BUDS

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INTRODUCTION

Killing frosts occur in the late spring and early fall over large areas of the United States, causing damage to the extent of several millions of dollars annually. The commonest method of protection is to heat the area by burning oil in pots distributed through the section that is endangered. Heating is resorted to on a large scale in the citrus fruit sections of California and less frequently elsewhere for the protection of such fruits as apples, peaches, and cherries. The success of this practice depends on the economical use of fuel and labor. If the predicted minimum temperature is lower than the "critical temperature" by an amount that exceeds the rise in temperature that the heaters will produce, or if the minimum temperature is above the "critical temperature," then the heaters should not be lighted. In order, therefore, to be able to tell when to light the heaters, it should be known how hardy the buds are. This paper gives the methods used and the results obtained from freezing more than 24,000 fruit buds, most of them being apples and peaches, and also the spring freezing temperatures and the yields of fruit in orchards near Logan, Utah, from 1913 to 1920.

THEORY OF INJURY DUE TO FREEZING

Pure water freezes at 32° F. Salts dissolved in water cause it to freeze at a lower temperature than this, the amount of the depression of the freezing point depending upon the nature of the salt dissolved and also upon the concentration of the solution. Thus, a 5 per cent common salt solution freezes at 27°, while a 30 per cent sugar solution freezes at only 29° F. W. H. Chandler[2] found that the expressed sap from fruit buds froze at 28° to 29° and in no case required a temperature below 28°. The sap from Elberta peach twigs, extracted in March, froze at 28.7°, while but two-thirds of the twigs of the same kind of fruit when subjected in March to a temperature as low as 10° froze. It is frequently found that some of the buds withstand temperatures as low as 20° and mature. The more concentrated the aqueous solution, the lower is its freezing point, and in general the amount of the substance, especially if it is organic, that will dissolve in water is but slightly affected by the substances that are already in solution. This allows the possibility of a

[1] Messrs. J. Z. Richardson, W. E. Goodspeed, and Scott Ewing rendered valuable assistance with the laboratory and field work.

[2] CHANDLER, W. H. THE KILLING OF PLANT TISSUE BY LOW TEMPERATURE. Mo. Agr. Exp. Sta. Research Bul. 8, 309 p., 3 pl.: chart. 1913. Bibliography, p. 305-309.

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very concentrated solution, and each of these substances has its influence in lowering the freezing point of the water largely independent of the others. For these reasons, a rather low freezing point of a solution is possible. A very concentrated juice, therefore, in the buds would be expected to freeze at a fairly low temperature. In spite of this, however, the unusual hardiness of some buds to freezing is really surprising. The difference in sensitiveness to cold of different buds on the same branch and of the same buds at different stages of development may be in part due to the difference in quality and concentration of the cell sap.

TABLE I.—*Classified list of the "danger points" for various kinds of fruit as given by different authors*

Kind of fruit.	Petals closed but showing color.	In blossom.	Fruit setting.	Authority.
	°*F.*	°*F.*	°*F.*	
Apples	27	29	30	W. M. Wilson.[1]
	27	29	30	P. J. O'Gara.[2]
	27	29	30	W. H. Hammon.[3]
	25	28	28	Paddock and Whipple.[4]
	25	28	28	W. H. Chandler.[5]
Peaches	20	25	28	W. M. Wilson.[1]
	29	30	30	W. H. Hammon.[3]
	29	30	30	P. J. O'Gara.[2]
	22	28	28	Paddock and Whipple.[4]
	25	27	27	Garcia and Rigney.[6]
Cherries	22	28	29	W. M. Wilson.[1]
	29	30	30	P. J. O'Gara.[2]
	22	28	28	Paddock and Whipple.[4]
Pears	27	29	29	W. M. Wilson.[1]
	29	29	29	P. J. O'Gara.[2]
	28	29	29	W. H. Hammon.[3]
	25	28	28	Paddock and Whipple.[4]
Plums	30	31	31	W. M. Wilson.[1]
	30	30	31	P. J. O'Gara.[2]
	30	31	31	W. H. Hammon.[3]
	22	28	28	Paddock and Whipple.[4]
Apricots	30	31	32	P. J. O'Gara.[2]
	30	31	32	W. H. Hammon.[3]
	22	28	28	Paddock and Whipple.[4]
Prunes	30	31	31	P. J. O'Gara.[2]
	30	31	31	W. H. Hammon.[3]

W. H. Chandler[7] reports minimum temperature and the resulting damage by natural frost. He also reports his work on the artificial freezing of detached branches. Garcia and Rigney[8] placed self-registering minimum thermometers in the orchard. After a freeze the percentage of frozen buds was determined, and in the fall the yield of the orchard was obtained. Their work covered five years.

[1] WILSON, Wilford M. FROST. *In* Bailey, L. H., ed. Standard Cyclopedia of Horticulture. v. 3, p. 1283. New York. 1915.

[2] O'GARA, P. J. THE PROTECTION OF ORCHARDS IN THE PACIFIC NORTHWEST FROM SPRING FROSTS BY MEANS OF FIRES AND SMUDGES. U. S. Dept. Agr. Farmers' Bul. 401, p. 20. 1910.

[3] GARCIA, Fabian, and RIGNEY, J. W. HARDINESS OF FRUIT-BUDS AND FLOWERS TO FROST. N. Mex. Agr. Exp. Sta. Bul. 89, p. 5. 1914.

[4] PADDOCK, WENDELL, and WHIPPLE, Orville B. FRUIT-GROWING IN ARID REGIONS . . . XX, 395 p. illus. New York. 1910.

[5] CHANDLER, W. H. OP. CIT., p. 140.

[6] GARCIA, Fabian, and RIGNEY, J. W. OP. CIT., p. 51.

[7] CHANDLER, W. H. OP. CIT. 1913.

[8] GARCIA, Fabian, and RIGNEY, J. W. OP. CIT.

When liquids are cooled to their freezing points, if there be none of the solid material present, they rarely freeze. They may be cooled several degrees further and kept for days without solidification taking place. The introduction of as small an amount of solid as one-hundred-thousandth part of a milligram is sufficient to cause freezing to begin. The smaller the amount of liquid taken the easier it is to superfuse it, and liquids contained in capillary tubes will remain for long periods of time below their freezing point without solidification taking place. The fact that the juice of the buds is confined in small capillary spaces will help to explain in part the unusual hardiness of the buds and the great difference in hardiness of buds that appear to be very similar. This phenomenon explains why they may be cooled below their freezing points and be warmed again without ice separating.

A classified list of the "danger points," as given by various investigators, is presented in Table I.

METHODS AND APPARATUS

NATURAL FREEZES

Each spring, for the last seven years, standard minimum thermometers have been placed in especially prepared but simple shelters in fruit trees of various orchards near Logan, Utah, and were read the day after a minimum temperature of 32° F. or lower was experienced. A record was made of the yield of fruit of the orchard for the season. The results of this work are found in Table II.

ARTIFICIAL FREEZES

The first work consisted in freezing detached branches of fruit buds in the laboratory by means of a specially designed thermostat, the air surrounding the buds being cooled by means of common salt and ice and warmed with an incandescent electric light, which was maintained constant at an arbitrarily determined temperature in the usual way with a relay. The extent of the injury was determined by cutting the buds open and counting those that had been damaged and then calculating the percentage that had been frozen.

Branches of trees were bent down into a vessel surrounded by a second air chamber, the latter being surrounded by a mixture of ice and salt. The minimum temperature was noted, the branch was tagged, and the further development of the buds was observed and the yield of fruit determined.

This method was modified by having the buds cooled by means of evaporating liquid carbon dioxid instead of using ice and salt. A tank of liquid carbon dioxid was connected to a metal coil that surrounded the bud chamber. The very cold gaseous carbon dioxid cooled the bud chamber, thereby cooling the buds to the desired temperature.

The fourth method consisted in freezing the whole tree by surrounding and covering it with a two-walled metal vessel containing ice and salt. The apparatus is shown in Plate 80.

The factors that determine the amount of damage done and that need to be controlled in the experiment are:

1. The kind of buds.
2. Their stage of development.
3. The minimum temperature.
4. The humidity.
5. The duration of the freeze.
6. The rate of thaw.

The first three are of most importance. By keeping the other factors fairly constant and varying the fifth and sixth, little difference in the results was noted. In almost every case in nature, as well as in our experiments, the humidity just as freezing occurs is practically 100 per cent. Transpiration into a closed vessel will ultimately give this result, and the best desiccating agents will not keep the humidity down appreciably. This holds true also in the orchard simply by the cooling irrespective of the transpiration, because even in such a dry section as the arid West, with a humidity as low as 50 per cent and a cool spring day of perhaps 45° F. noon temperature, the dew point would be 27.5° F., which is about the temperature at which slight damage is caused. Where the humidity is higher, as it is in most places east of the Rocky Mountains and west of the Sierra Nevada Mountains, the dew would collect and the humidity would be 100 per cent even before the buds had cooled to the danger temperature. In all the work here reported the humidity was practically 100 per cent.

While the whole tree was being frozen, several minimum thermometers were suspended at different places in its branches, and the air was stirred by an electric fan driven with storage batteries. The humidity was determined by a continuous reading hygrometer, and the rate of thaw and duration of freeze were recorded by means of a thermograph that was placed in the branches.

The cost of the different methods is about the same for freezing the same number of buds. Adjoining limbs and adjacent trees were thinned to the extent that the branch or tree had been thinned by the frost, and the yields in the fall were noted for comparison. A greater variation in the factors, and thus a greater number of different experiments, can be secured for the same expenditure by freezing the branches on the tree rather than the whole tree.

The results of the natural and artificial freezing experiments are presented in Tables II to IV.

TABLE II.—*Temperatures produced and percentage of buds killed by artificial freezing*

Kind of fruit.	Number of buds.	Development.	Temperature.	Percentage of damage.
			°F.	
	110	Showing color	22.5	88
	1,935	do	25	45
	2,172	Full bloom	24	81
	101	do	24.5	56
	813	do	25	54
	1,828	do	26	16
	1,490	do	26	100
	28	do	26.5	36
Ben Davis apples	127	do	27.5	54
	4,217	do	28	0
	12	do	28.5	0
	29	Fruit setting	25.5	93
	49	do	26.5	40
	40	do	26.5	23
	33	do	27.5	21
	48	do	27.5	59
	55	do	27.5	62
	58	do	28	46
	1,715	Showing color	17.5	64
	1,846	do	18	75
	35	do	20	66
	675	do	22.5	76
	111	do	22.5	76
	277	do	24	89
	361	do	24	79
	514	do	25	96
	380	do	25	74
	586	do	25	77
	1,195	do	25	97
	189	do	26	80
	372	do	27.5	79
	349	Full bloom	22	100
	38	do	24	63
	22	do	24	64
	42	do	25	58
	62	do	25	28
	35	do	25	72
Elberta peaches	1,062	do	25	65
	42	do	26	40
	.....	do	26	48
	355	do	26	78
	749	do	26	54
	194	do	26	57
	37	do	27	0
	27	do	27	0
	507	do	27	55
	.....	do	28	55
	.....	do	28	33
	80	Fruit setting	24.5	30
	.....	do	25	100
	16	do	26	75
	70	do	26.5	48
	49	do	27	75
	78	do	27.5	56
	.....	do	27.5	48
	.....	do	28	43
	.....	do	29	33.3

TABLE III.—*Temperatures produced and number of mature fruits harvested by artificial freezing*

Kind of fruit.	Number of buds.	Development.	Temperature.	Number of fruits harvested.
			°F.	
Ben Davis apples	30	Full bloom	20	4
	38	do	20	9
	18	do	20	2
	60	do	20	0
	19	do	21	0
	39	do	22	3
	36	do	22	4
	12	do	23	0
	19	do	23	0
	37	do	23	0
	119	do	23	14
	32	do	24	4
	149	do	25	8
	64	do	25	3
	55	do	25	0
	44	do	25	0
	45	do	25	0
	89	do	28	7
	81	do	28	9
	35	do	28	7
	45	do	28	7
	71	do	28	0
Control limbs, untreated	108	Full bloom		13
	74	do		8
	122	do		15
	63	do		10
	141	do		17
Ben Davis apples	71	Fruit setting	20	0
	52	do	25	0
	87	do	25	5
	64	do	25	0
	88	do	25	0
	105	do	25	0
	106	do	28	8
	69	do	28	0
	68	do	28	3
	69	do	28	0
	133	do	28	0

TABLE IV.—*Result of natural freezes*

Kind of fruit	Showing color.	Full bloom.	Fruit setting.	Percentage killed.
Apples	28, 25, 27	24, 28	28, 28. 5	32
	27. 5, 27. 5	30. 5	31. 5, 30	8
	26			5
		26		41
			30	0
			29	0
	27			0
	28			0
	29			0
			28	0
	26, 25	32		0
	29, 29, 30		32	

TABLE IV. *Result of natural freezes*—Continued

Kind of fruit.	Showing color.	Full bloom.	Fruit setting.	Percentage killed.
Prunes	22	.....	.....	0
	.....	26	.....	0
	.....	26	.....	0
Sweet cherries	22	.....	.....	44
	.....	.....	26	0
	.....	.....	26	0
	26, 25	.....	32, 31	0
	29, 25, 27	.....	.....	0
	30	.....	.....	0
	.....	26	.....	53
	29, 29	.....	.....	22
	30	.....	.....	30
	31, 32	.....	.....	0
	.....	25, 30	.....	50
Sour cherries	22	.....	.....	61
	22	.....	.....	23
	.....	26	.....	0
	.....	26	.....	10
	.....	26	.....	48
	26	.....	.....	20
	31, 23, 32, 25, 30	.....	.....	0
Elberta peaches	26	.....	.....	0
	.....	32	.....	0
	25	.....	.....	0
	.....	32	.....	0
	28	.....	.....	0
	25	.....	.....	0
	.....	30	.....	0
	.....	.....	30	0
	24	.....	.....	54
	22	.....	.....	36
	.....	26	.....	0
	27. 5, 27. 5	30. 5	31. 5, 30	56
Apricots	29, 25	.....	.....	0
	27, 30	.....	.....	20
	.....	26	32	20
	.....	22	.....	55

SUMMARY

(1) Efficient orchard heating demands an economical use of labor and fuel and requires knowledge of the temperatures that cause injury to the buds.

(2) This paper contains the results of seven years' experiments in freezing 24,000 apple, peach, cherry, and apricot buds, together with a record of the natural freezes that occurred in the orchards near Logan, Utah, during the same period.

(3) Ben Davis apple buds in full bloom have experienced temperatures of 25°, 26°, and 27° F. without injury, but 28° usually kills about one-fifth. Twenty-nine degrees or above are safe temperatures. Twenty-five degrees kills about one-half and 22° about nine-tenths. On several

occasions, however, apples matured on branches that experienced 20° when the buds were in full bloom.

(4) With Elberta peach buds in full bloom, 29° F. or above are the safe temperatures, because even though occasionally 26°, 27°, and 28° do no damage, yet on most occasions 28° will kill from one-fourth to one-half. Twenty-six degrees kills about one-half of them and 22° about nine-tenths. Temperatures as low as 18° have failed to kill all of them.

(5) With sweet cherry buds in full bloom, 30° F. is the safe temperature; 25°, 26°, 27°, 28° have done no damage; but 29° usually kills about one-fifth. Twenty-five degrees usually kills about one-half, and when the buds were showing color 22° killed only two-fifths of the buds.

(6) Sour cherries are hardier than the sweet varieties. When the buds were showing color 23° F. did not harm them, and when they were in full bloom 26° killed but one-fifth and 22° only two-fifths of them.

(7) With apricots, 29° F. is the safe temperature; 26° and 27° killed about one-fifth and 22° killed one-half. They are fairly hardy, but they bloom so early that they are frozen oftener than any of the other fruits studied in the experiments.

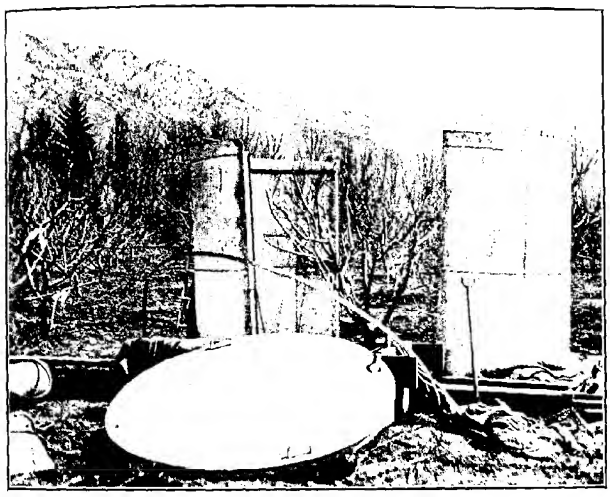
(8) The foregoing figures refer to the buds when in full bloom. Starting from this stage, the earlier the stage of development the hardier the buds are; and in general, when the fruit is setting the injury is from 5 to 10 per cent more than when they are in full bloom.

(9) Sour cherries are the hardiest, and then follow in order apples, peaches, apricots, and sweet cherries.

(10) The fact that the same branch of buds will on one occasion experience 27° F. with 25 per cent injury and on another occasion take the same temperature with no injury is no doubt due to the fact that the juice is contained in capillary cells and supercooling results—that is, the buds are cooled below the freezing point of the juice without the freezing taking place. The great difficulty of killing all the buds even at extremely low temperatures is due to the same cause together with the fact that the cell sap may be very concentrated. Differences in the hardiness of the different kinds of buds and also of the same buds at different stages of development is due to differences in quality and concentration of the cell sap.

PLATE 75

Apparatus for freezing entire tree.



EFFECT OF VARIOUS CROPS UPON THE WATER EXTRACT OF A TYPICAL SILTY CLAY LOAM SOIL

By G. R. STEWART, *Chemist, Hawaiian Sugar Planters' Association*, and J. C. MARTIN, *Assistant Chemist, California Agricultural Experiment Station*

The senior author has previously reported a series of investigations carried on at the California Agricultural Experiment Station upon the changes which took place in the water extracts from a group of selected soils. These consisted of six silty clay loams and seven fine sandy loams. All were typical soils brought from various places in California and represent a considerable range of past treatments and some variations in known productive capacity. A large quantity of each soil was brought to the Experiment Station at Berkeley, where it was sifted, mixed, placed in two uniform containers, and afterwards kept under controlled conditions. A crop of barley was raised upon all the soils during the first year of the experiment in order to bring them into a somewhat comparable state of tilth. During the second season one container of each soil was cropped and the other was maintained as an uncropped duplicate. Notable differences were found in the amounts of water-extractable constituents from the cropped and the uncropped soils. The water-soluble nitrates, calcium, potassium, and magnesium were generally higher in the uncropped soils. Considerable differences were also observed in the amounts of water-soluble constituents extracted from the different uncropped soils. Further details of the experimental methods and of the results obtained may be found in the original publication.[1]

The conclusion from our previous work, that barley reduces the nitrates of soils to a low and fairly uniform magnitude independently of the soils' crop-producing power and also tends to reduce the amounts of other water-extractable constituents, seemed to require that the observations be extended to include the effects of other crops. It was also deemed desirable to study the effect of varying numbers of plants in accelerating the changes observed and if possible to ascertain the rate of movement of water-extractable substances through the soil.

The experimental work consists of two separate studies, one to cover the specific effect of different types and numbers of plants, the other to shed light on the movement of solutes through the soil.

[1] STEWART, Guy R. EFFECT OF SEASON AND CROP GROWTH IN MODIFYING THE SOIL EXTRACT. *In* Jour. Agr. Research, v. 12, no. 6, p. 311-368, 24 fig., pl. 14. 1918. Literature cited, p. 364-368.

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EFFECT OF TYPE AND NUMBER OF PLANTS

A large portion of Yolo silty clay loam soil was sifted into a group of eight containers. Each container was of the same size as those previously used, 30 inches wide, 60 inches long, 18 inches deep, and held approximately 1,800 pounds of soil.

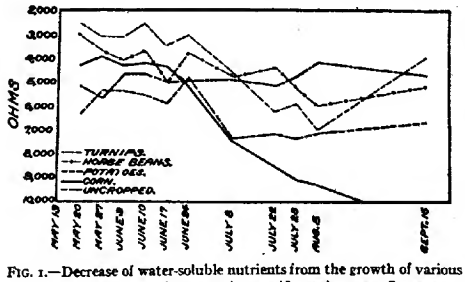

FIG. 1.—Decrease of water-soluble nutrients from the growth of various crops, as shown by increases in specific resistance. Crops were planted May 13, and soil was sampled on dates given.

One container was planted to Golden Ball turnips, one to horse beans, one to Early Golden Bantam corn, one to Burbank potatoes, and three to barley, the latter having, respectively, 24, 50, and 72 plants each. In addition, one container was left uncropped as a control.

Water extractions were made at intervals of one to two weeks throughout the major portion of the growing season. This period extended from the middle of May to the end of September. All the crops except the corn matured normally. The cool nights of the San Francisco Bay region prevent corn planted in the spring from maturing till late in the fall. The results with this crop, however, were of such a nature that observations thereon became unnecessary after the maturation of the other crops and were accordingly discontinued at that time.

The extractions were made in the proportion of 1 part of soil to 2 parts of water. The mixture was triturated in a mortar for three minutes and then filtered upon a medium grade of semi-quantitative paper in an ordinary funnel. The first portions were poured back until reasonably clear filtrates were obtained. The conductivity of this solution was then determined by the Wheatstone bridge and is expressed in the graphs as ohms of specific resistance. An increase of resistance, therefore, represents a lowering of the concentration of electrolytes present. Work performed in this laboratory on similar solutions has shown that this method gives results which are comparable to those obtained by accurate

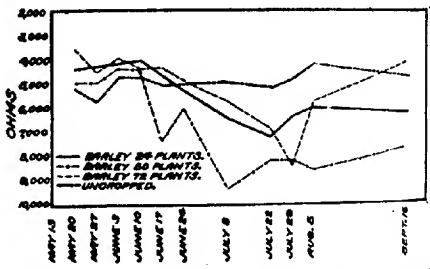

FIG. 2.—Decrease of water-soluble nutrients from varying numbers of barley plants, as shown by increase in specific resistance. Crops were planted May 13, and soil was sampled on dates given.

determinations of total solids. The results of these conductivity determinations are plotted in figures 1 and 2.

Here we find that all the crops have reduced the concentration of the water extracts during the middle of the growing season. It is interesting to note in the cases of the barley crops that even the smallest number of plants was sufficient to effect a substantial reduction of water-extractable solutes by the time the plants had become well established. The uncropped soil, on the other hand, maintained a remarkably uniform concentration throughout the period of observation.

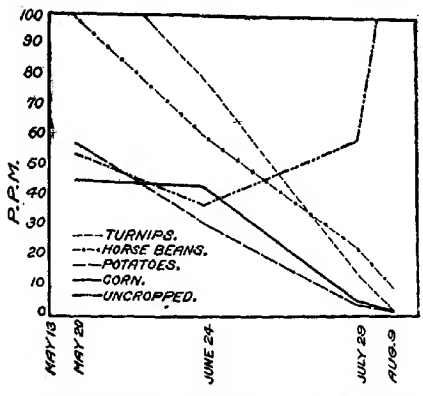

FIG. 3.—Decrease of water-soluble nitrates from the growth of various crops. (Graphs=½ NO_3.) Crops were planted May 13, and soil was sampled on dates given.

Nitrates were determined at a few periods, and these results are given in graphs 3 and 4.

Here we see that each crop at maturity had depressed the soil's nitrate content to a minimum. The uncropped soil constantly remained on a higher level.

MOVEMENT OF SOLUTES THROUGH THE SOIL

In this experiment two containers of the same soil were placed in the greenhouse and buried in the ground, level with the floor for heat insulation. Two rows of sugar beets were planted across one end of one container. These were spaced 6 inches apart in the row and 9 inches between rows. The remainder of the container, some 40 inches in length, was left bare. Two rows of barley were planted in one end of the other container. The plants were spaced 6 inches apart and 6 inches between rows. This left 40 inches of unoccupied ground.

The crops were started in December and were allowed to grow until the following March. By that time the beets were about 2 inches in diameter and the barley was fully headed.

Periodic observations of the concentration of the soil solution were made by means of freezing-point determinations. Two samples were always taken from each container, one from between the rows of beets or barley and the other near the bare end of the tank. The freezing-point depressions for both groups of samples are given in figure 5. The last sample in April represents the condition we have previously observed in soils when barley had made about the same growth.

At this time a longitudinal section was cut in the soil, and the root extension of both crops was studied. With the sugar beets it was found that a thick, matted growth of fine rootlets extended from the second row of beets to the extreme end of the container, 41 inches in all. Many of these rootlets were branches from the main fleshy feeders. These extended laterally throughout the bare end of the tank. The main barley roots were found to extend 32 inches from their plant sources with the finer rootlets extending 1 foot further toward the bare end of the container. A portion of the roots also extended to the bottom of the container and ran almost to the end wall.

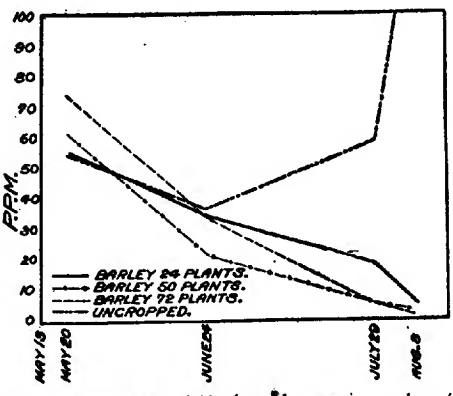

FIG. 4.—Decrease of water-soluble nitrates from varying numbers of barley plants. (Graphs=⅓ NO_3.) Crops were planted May 13, and soil was sampled on dates given.

The soil solution during the early stages of growth of both barley and beets appeared to have a significantly lower concentration in the near neighborhood of the plants than at a distance therefrom. It was not until the early part of April when the plants had reached a considerable size that the soil solutions in the cropped and uncropped ends of the containers approached each other in concentration. Unfortunately for the original objective of the experiment, the roots of the plants, in both cases, appear to have penetrated the soil mass of the bare ends of the containers about as rapidly as the concentration of the soil fell off.

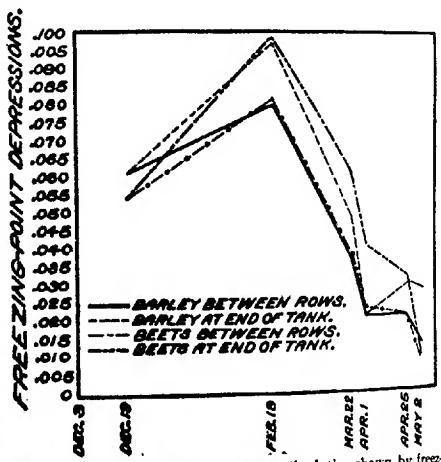

FIG. 5.—Decrease in the concentration of soil solution shown by freezing-point depression. Crops were planted December 3, and soil was sampled on dates given.

There is, therefore, no proof here, either as to the rate of translocation or the distance through which the soil solutes may move by diffusion. But since the losses of concentration of the soil solution appear to be somewhat proportional to root penetration, it would seem probable that the rate of movement of solutes through the soil is less than the rate of growth of the roots of normal barley and beets.

CONCLUSIONS

The gain in specific resistance and the decline in nitrate content of the water extracts of soils planted to different crops warrant us in extending the conclusions heretofore drawn from observations of the effects of barley. It is clear that the phenomena noted are not peculiar to the barley plant but are characteristic of all the plants tested and probably apply to all chlorophyll-bearing plants which root in the soil. The extent of the reduction of concentration observed is variable with different crops. We may not put too much stress upon the magnitudes of these differences, however, because of the obvious differences in growth habits and life history of the plants considered. It is interesting to note, however, that corn which is commonly regarded as a "gross feeder" in ordinary fertilizer practice has increased the specific resistance of the water extracts more rapidly and completely than the other plants.

The second experiment sheds little light on the rate of movement of solutes toward the plant roots. Inasmuch, however, as reductions in concentration of water extracts of soil at a distance from growing plants did not take place until that portion of the soil had become filled with roots, it would seem that rapid and extensive movements of soil solutes are probably not an incident of normal plant absorption.

SUMMARY

(1) The effect of crops of corn, horse beans, potatoes, turnips, and barley upon the water extract from a typical silty clay loam was studied throughout the growing season.

(2) All the crops discussed in this paper reduced the concentration of the water extract during the height of the growing season.

(3) The nitrate content of the soil was reduced to a very low figure by all crops.

(4) An experiment in which the concentration of the soil solution was studied by means of observations of freezing-point depressions in the immediate vicinity and at a distance from the plants showed that concentrations are not significantly reduced until the portion of the soil sampled is filled with plant roots.

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